MUSHROOM
RESEARCH
STATION
YAXLEY
PETERBOROUGH

REPORT
for year 1951

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PREFACE

by the Chairman, Fred. C. Atkins, Esq.

A slightly better price for mushrooms in the wholesale markets in 1951 might have been expected to result in a more encouraging response to the several appeals I made to the Industry during the year on behalf of the Board of Directors. Regrettably we had to take full advantage of the Ministry's generous offer to contribute up to 75 per cent. as grant-in-aid.

We are most grateful for the very considerable help provided by those growers, salesmen, sundriesmen and friends, at home and abroad, who enabled us to scrape through, and I personally would like to place on record the many kindnesses and tangible support accorded during my term in office.

My resignation from the Chairmanship at the last Annual Meeting was prompted by two thoughts. Firstly, the whole Industry must by now be aware of the fact that I fail completely to comprehend why some growers are so blind as to see no value in research, and constant repetition of *my* viewpoint tends to weaken interest in the main annual appeal ; the time was obviously ripe for the appearance of a fresh advocate in this senior office. Secondly, the moment was approaching when the sponsoring Mushroom Growers' Association would be compelled to inform the Ministry of Agriculture that the responsibility for finding even one-quarter of the funds required could not be borne very much longer.

A decision one way or the other may have to be made in 1952, and I felt it would be advisable if the Chairman of the M.R.A. could speak to the Ministry with the authority of the M.G.A. Chairman.

So it was, with less misgivings than I might have had, that I made way for Mr. John Stewart-Wood. This dual office makes great demands on the holder's time and strength, and if I have done anything to deserve your goodwill I pray you will show it by supporting him in whatever steps are found necessary to keep the Research Flag flying indefinitely.

While congratulating the Director of Research and his Staff on the provision of a splendid Synthetic Compost formula, I would like to thank them for their many courtesies and to wish them comparable success in the Soil Problem and in the new Disease Room, which opens in the spring.

FRED. C. ATKINS,

Chairman, 1950/51.

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GENERAL REPORT

During the past year work on casing soil has got into its stride, and it has become the most important part of the programme. Because laboratory and cropping experiments on casing soil are so closely related, all this work is reported as one section, separately from the other work of the Chemistry Department and from other Cropping Experiments. The general plan on which we are working was described in last year's report. The methods described then have been used to examine four soils, which have been used in small scale cropping experiments. In experiments on the effect of watering, layers of soil made up to resemble the casing soil of a bed were found very sensitive to the quantity of water applied at one time, and to the total watering per week. Overwatering, well within the range possible in commercial growing, started to break down the soil surface, and in four weeks reduced the soil at the bottom of the layer to a fine sludge-like condition. These observations are being continued and extended to include the use of various types of spray.

The pot experiment described on p. 31 was devised mainly so that the water balance could be followed on various soils and systems of watering. Incidentally it provided a much larger number of experimental units than could be brought into use in any other way, and the pots will be most useful for future work on the relation between watering and fruiting. The four soils used were our own, a lighter soil rich in organic matter which was known to give good crops, a light soil reputed to crop badly, and this soil with the addition of peat. In our experiments this soil gave a reasonable yield, which was not appreciably altered by the addition of peat, except that it became more tolerant of variations in watering. Its failure elsewhere was presumably due to other causes.

The results show that frequent watering to allow only small fluctuations in soil moisture gave the best yields. As would be expected, extremes of over and under-watering gave reduced yields. Thus watering ' little and often ' gave better results on both visible structure and yield of mushrooms than using the same total amount of water in larger doses and at longer intervals.

Cropping experiments on soil pH and calcium content have confirmed previous reports that casing soil with too high pH is undesirable.

A surprising result was the great difference in yield between fine and coarse fractions of the same soil. This must be attributed to the greater freedom of air movement between the larger lumps. These beds were in crop in the warm weather of early summer when respiration in the beds would be fairly high.

Another cropping experiment showed that barley straw can be used to replace half of the wheat straw in synthetic compost, but barley is not very safe to use alone.

No doubt horse manure containing a mixture of wheat and barley straws could equally well be used, but it would be more important to use this fresh, before the softer barley straw was too much broken down.

Urea again gave a satisfactory result in place of dried blood. No difference was found between the third turn and filling for addition of Activator No. 2.

Doubling the quantity of superphosphate gave a very small increase in yield, particularly toward the end of the crop, but doubling the trace elements had no effect.

In an experiment on conditions of stacking and compost in the beds only small differences were observed, but the tendency was for relatively dry synthetic compost (65% moisture at filling) to crop later but give higher yields than wetter compost (77% moisture).

As in previous experiments, beds cased late (21 days after spawning) gave a better yield than those cased after 7 or 14 days. This result would probably be different under conditions of high temperature and humidity giving a rapid spawn run, as for example where live steam is used.

Truffle has been our main interest among the diseases. Attempts to determine more precisely the conditions under which copper sulphate controlled the growth of Truffle were unsuccessful owing to variations and changes in moisture content and pH of the small quantities of compost used in the tube experiments. Growth of Truffle was generally associated with high moisture in the composts. In one experiment on a farm the copper sulphate treatment was applied to compost which did not develop Truffle whereas the untreated beds did. More such trials will be arranged in 1952.

A farm experiment on the control of Bubble (*Mycogone perniciosa*) by two new fungicides was highly successful, both giving a very substantial degree of control whereas the older treatment with Bordeaux mixture had little effect. The exact results likely to be obtained in practice with these new fungicides must depend on conditions, but their potential value is already established.

In experiments on bacterial pit, the incidence of disease was reduced after spraying with various substances, but satisfactory control was not obtained.

New disease room

A new room has been built on to the end of the laboratory so that experiments on diseases can be carried out under controlled conditions and without the danger of introducing infection into the ordinary cropping experiments.

The room is small, measuring 10 ft. by 6 ft. and has three bays, each with four shelves. Each shelf will normally bear three trays of $1\frac{1}{2}$ sq. ft., giving a total of 36 trays. The trays can be filled, spawned and grown in the test houses up to the stage when disease is to be introduced, so that each experimental set need only occupy the disease room for a part of the normal cropping period.

The room has 12 inch cavity brick walls, the 3 inch cavity being packed with rock wool to improve insulation ; the double roof is of asbestos interlined with thick Fibreglass. There are ventilators near the roof and floor, connected by a vertical shaft and fitted with shutters and a fan so that air can be drawn in, circulated within the room in a closed circuit, or circulated with some replacement by fresh air. Heating is by electric tubes thermostatically controlled, and the air can be humidified if necessary.

The disease room will be in use in 1952, for experiments on the control of Truffle and the three parasitic diseases, Dactylium, Mycogone and Verticillium.

We are most grateful to Messrs. Noble Mushrooms Ltd. for a special contribution toward the cost of building this room.

The recent increase in the price of straw has stimulated an interest in possible alternatives, and a survey of these prepared during the year is included as a matter of possible interest to growers in districts where straw is particularly scarce.

Revision of the formula for M.R.A. compost has been considered, but no experiments carried out since it was first published have promised substantial improvements, except that when urea is available it will be a cheaper and equally satisfactory alternative to dried blood.

Miss C. W. H. Duncan resigned in August and Miss D. G. Gandy was appointed Microbiologist in her place.

In addition to the usual account of the year's work this Report includes an account by Mr. Fred. C. Atkins, Chairman of the Association and Technical Director of Messrs. Noble Mushrooms Ltd., of their experience in the preparation and use of M.R.A. synthetic compost on a commercial scale. It is unusual to include contributions by non-members of the staff, but the author and the subject are so closely connected with the Association that the Report is a fitting place for this work to be described.

We wish to thank Messrs. H. Mount & Son for gifts of fresh spawn used in the experiments on Truffle ; Messrs. Plant Protection Ltd. and Murphy Chemical Co. Ltd. for gifts of fungicides used in experiments ; those growers who have sent specimens of casing soils for experimental purposes ; Messrs. Noble Mushrooms Ltd., Mr. Stanley Middlebrook, Mr. H. Kilian, and Mr. A. G. Lamberth for facilities for experiments on disease ; and other growers and research workers who have helped us with information or advice.

CROPPING EXPERIMENTS — R. L. Edwards

Experiment 15

This factorial experiment was arranged to test normal and double quantities of trace elements and of superphosphate in synthetic compost. Six stacks were made with each of the four treatments, as shown with results in Table 1.

In the cropping house three sets of beds were cased 7, 14 and 21 days after spawning, making twelve treatments in all. The results of the casing experiment are shown in Table 2. The variation in phosphate and trace elements had little effect on yield, but the higher levels gave a longer picking period. There was also some indication of exhaustion in the number, size and weight of mushrooms picked towards the end of the crop.

The time of casing had a pronounced effect, and as in previous experiments, late casing gave the best yield, without delaying the start of cropping.

In this case more mushrooms were produced on the late cased beds, with little compensating effect on size. It is also noteworthy that the effect persisted throughout the crop, and was not merely an initial spurt of pent up energy due to the delay in casing. It seems that growth of mycelium in uncased beds has some quality which is lacking in growth made after casing.

Conclusion.

There was some indication that increased quantities of superphosphate and trace elements were beneficial towards the end of the crop.

Beds cased 21 days after spawning gave a much better yield than those cased earlier.

Table 1. Effect of phosphate and trace elements.

Superphosphate (all at last turn)	28	28	56	56 lb./ton of straw
Trace element mixture	2	4	2	4 ,,
First picking	74	71	67	71 ± 5 days from spawning
Total Picking period	64	76	83	82 days
Fruiting—				
4 weeks	3·2	2·1	2·3	1·7 mushrooms/sq. ft.
8 weeks	4·7	4·2	4·3	3·1 ,,
12 weeks	7·6	8·1	8·7	8·1 ,,
8-12 weeks	2·9	3·9	4·4	5·0 ,,
Yield—				
4 weeks	5·5	4·3	4·6	3·8 oz./sq. ft.
8 weeks	7·6	7·7	8·3	6·6 ,,
12 weeks	10·1	12·5	13·6	12·4 ± 2·7 ,,
8-12 weeks	2·5	4·8	5·3	5·8
Average size—				
0-4 weeks	1·72	2·05	2·00	2·24 oz./mushroom
4-8 weeks	1·40	1·62	1·85	2·00 ,,
8-12 weeks	0·86	1·24	1·20	1·16 ,,

Table 2. Effect of casing time

Beds cased	7	14	21 days after spawning
First picking	65	69	66 ± 1·7 „ „ „
Total picking period	82	80	78 days
Fruiting—			
4 weeks	1·3	2·1	3·5 mushrooms/sq. ft.
8 weeks	2·7	3·7	5·8 „
12 weeks	5·7	8·0	10·3 „
8-12 weeks	3·0	4·3	4·5 „
Yield—			
4 weeks	3·0	4·2	6·5 oz./sq. ft.
8 weeks	5·1	7·0	10·5 „
12 weeks	8·4	12·0	16·0 ± 1·4 „
8-12 weeks	3·3	5·0	5·5 „
Average size—			
0-4 weeks	2·31	2·00	1·86 oz./mushroom
4-8 weeks	1·50	1·75	1·74 „
8-12 weeks	1·10	1·16	1·22 „

The best average yield from a group of beds was 1·5 lb./sq. ft., the best bed gave 1·75 lb./sq. ft.

Experiment 16

Three sets of composts were made, using wheat straw, barley straw, and a mixture of equal parts of wheat and barley.

Four stacks of each were made, using standard M.R.A. activators. Four beds were filled from each stack, and the following lime treatments were given to the local clay-loam subsoil before casing. This used four of the six shelves in the house.

No lime
5 lb. hydrated lime per ton
20 lb. hydrated lime per ton
27 lb carbonate of lime per ton (ground chalk)

The results are shown in Tables 3 and 4.

A separate small experiment was arranged using one shelf of 12 beds to study the effect of screening the soil. A $\frac{1}{4}$" screen was used, beds being cased with the coarse fraction, the fine fraction, and the mixed soil.

The results are shown in Table 5.

The sixth shelf was used for the pot experiments described on p. 31 of this Report.

There was no difference in yield between wheat and mixed straws. The yield from barley straw was slightly lower, but the difference was not statistically significant.

However, there was quite an obvious difference in texture of the compost, the barley straw becoming very much softer after composting, and it was clear that barley straw alone could very easily become soggy if it was made too wet, packed too tightly, or over-composted. Barley

straw is therefore not recommended for use alone as an alternative to wheat straw, but it can quite well be used in place of half of the wheat straw. It is recommended that where the wheat straw is soaked and then allowed to heat up in the bales to soften it, barley straw should be wetted later and should not be heated, because the heating process may soften it too early. Both kinds of straw can be effectively wetted by the drip-pipe method described in the Annual Report for 1946-48.

The lime treatments produced large differences in yield. The very high pH of the soils treated with hydrated lime soon fell to a value below 9, but some effect of heavy liming remained and these soils still had slightly higher pH values even at the end of the cropping period. The figures for successive 4—weekly periods show that the effect of heavy liming diminished as cropping proceeded. It is interesting to note that the main effect was on the number of mushrooms produced, and the smaller number of mushrooms on limed soils was partly compensated by an increase in size.

The test with coarse and fine soils was intended to study the effect of resultant differences in aeration.

The coarse fraction of soil produced an earlier crop, more mushrooms and a greater total yield than either the mixed or fine soil. The rate of production was higher throughout the crop, not merely at the start.

The difference in yield was much greater than had been expected, and more investigation is needed before the results can be explained with any certainty or applied in practice.

Table 3. Wheat, barley and mixed straws

	Wheat	Barley	Mixed	s.e.	
First pinheads	56	61	60		days from spawning
First pickng	67	71	70	±1·4	„ „ „
Fruiting—					
4 weeks	7·1	6·1	7·3		mushrooms/sq. ft.
8 weeks	14·6	12·7	14·7		„
12 weeks	18·3	15·0	18·0	±1·6	„
Yield—					
4 weeks	8·8	7·8	8·9		oz./sq. ft.
8 weeks	17·2	15·8	17·6		„
12 weeks	21·1	18·6	21·2	±1·6	„
Average size—					
0-4 weeks	1·24	1·28	1·22		oz./mushroom
4-8 weeks	1·18	1·24	1·20		„
8-12 weeks	1·15	1·24	1·18		„

The best yield from a group of beds similarly treated was 1·7 lb./sq. ft. and from a single bed 2·4 lb./sq. ft.

Table 4. Lime treatments of casing soil

	None	hydrated 5 lb.	hydrated 20 lb.	carbonate 27 lb.	s.e.	per ton of soil
Initial soil pH	7·5	10·4	12·3	7·8		
First pinheads	62	57	59	57		days from spawning
First picking	72	68	70	67	±1·5	,, ,, ,,
Fruiting—						
4 weeks	3·2	6·6	4·0	13·5		mushrooms/sq. ft.
8 weeks	7·7	13·6	9·8	25·0		,,
12 weeks	11·1	17·5	12·7	27·1	±1·4	,,
Yield—						
4 weeks	5·1	9·0	6·5	13·3		oz./sq. ft.
8 weeks	11·4	17·4	14·6	24·3		,,
12 weeks	14·8	22·0	17·6	26·8	±1·3	,,
Average size—						
0-4 weeks....	1·59	1·36	1·61	0·98		oz./mushroom
4-8 weeks....	1·48	1·28	1·49	0·97		,,
8-12 weeks....	1·33	1·26	1·39	0·99		,,
Soil pH at emptying	7·5	7·7	8·0	7·4		
Fruiting—						
0-4 weeks....	3·2	6·6	4·8	13·5		mushrooms/sq. ft.
4-8 weeks....	4·5	7·0	5·8	11·5		,, ,,
8-12 weeks....	3·4	3·9	2·9	2·1		,, ,,
Yield—						
0-4 weeks....	5·1	9·0	6·5	13·3		oz./sq. ft.
4-8 weeks....	6·3	8·4	8·1	11·0		,, ,,
8-12 weeks....	3·4	4·6	3·0	2·5		,, ,,

Table 5. Effect of casing with screened soil

	Coarse	Fine	Mixed	s.e.	
First pinheads	54	89	67	±6	days from spawning
First picking	65	97	80	±6	,, ,, ,,
Fruiting—					
4 weeks	4·5	1·5	2·0		mushrooms/sq. ft.
8 weeks	11·8	2·8	5·8		,,
12 weeks	20·8	3·8	9·5	±2·4	,,
Yield—					
4 weeks	8·8	3·2	4·5		oz./sq. ft.
8 weeks	22·2	5·8	11·0		,,
12 weeks	34·2	7·0	15·5	±2·6	,,
Average size—					
0-4 weeks	1·96	2·13	2·25		oz./mushroom
4-8 weeks	1·84	2·00	1·71		,,
8-12 weeks	1·33	2·20	1·22		,,

Experiment 17

This experiment was designed to study the effect of some variations in cultural management.

Four kinds of stacks were made :

wet tight	dry tight
wet loose	dry loose

There were six stacks of each kind, all made with the standard M.R.A. activator and a mixture of wheat and barley straw.

The wet stacks were made as wet as possible and were kept as wet as we considered possible without damage to the crop. The dry stacks were watered lightly at stacking and kept as dry as possible.

Tight stacks were trodden hard at stacking and at each turn ; loose ones were not trodden and each layer of compost was patted down with a fork.

Table 6. Effect of stack conditions on yield

Stacks made	Wet tight	Wet loose	Dry tight	Dry loose	s.e.	
Average moisture content at filling	77·9	76·9	64·8	65·2		%
Stack temperature	54	46	52	50		°C.
Bed temperature	43	44	41	42	±1·7°	C. after peak heat
Average depth of compost after cropping	4·3	4·6	5·3	5·4		inches
First pinheads	51	45	55	55	±3·5	days from spawning
First picking	59	54	61	62	±3·5	,, ,, ,,
Fruiting—						
4 weeks	4·3	3·9	5·2	5·3		mushrooms/sq. ft.
8 weeks	12·4	11·1	12·8	12·5	±3·0	,,
12 weeks	17·3	17·7	21·4	21·7	±3·8	,,
8-12 weeks	4·9	6·6	8·6	9·2		
Yield—						
4 weeks	5·0	5·8	5·9	6·3		oz./sq. ft.
8 weeks	12·3	14·4	13·0	13·6	±3·2	,,
12 weeks	15·9	19·4	18·7	19·4	±3·5	,,
8-12 weeks	3·6	5·0	5·7	5·8		,,
Average size—						
0-4 weeks	1·16	1·49	1·14	1·19		oz./mushroom
4-8 weeks	0·90	1·19	0·93	1·00		,,
8-12 weeks	0·73	0·75	0·66	0·63		,,
Whole period	0·92	1·10	0·88	0·89		,,

When the beds were laid, each of these stacks was treated in three ways :—

15 bags of compost per bed, packed tightly
10 bags per bed packed loosely to give the same depth as the tight beds
10 bags per bed packed tightly.

These gave approximately 24 lb. and 16 lb. of the wet composts per sq. ft. and rather less than these amounts from the dry stacks which produced a stiffer, more bulky compost.

The results are shown in Tables 6, 7 and 8. Tight stacks reached higher temperatures, the wet tight group being hottest. This was, of course, synthetic compost, which is never quite as tight as horse manure and is usually very open when first stacked.

The wet compost started to crop a week earlier, but did not give a higher yield. Dry compost gave more mushrooms, particularly in the last four weeks, but they were smaller and did not produce an increased weight of crop.

Table 7. Effect of bed conditions on yield

Beds made	Deep tight	Deep loose	Shallow tight	s.e.
Average bed temperature after peak heat	45	42	41	±0·4° C.
Average depth of compost after cropping	6·2	4·9	3·7	inches
First pinheads	51	52	51	±1·05 days from spawning
First picking	59	59	59	±1·0 ,, ,, ,,
Fruiting—				
4 weeks	4·1	5·1	4·8	mushrooms/sq. ft.
8 weeks	11·9	11·8	12·8	±1·0 ,,
12 weeks	20·5	18·4	19·4	±1·2 ,,
8-12 weeks	8·6	6·6	6·6	,,
Yield—				
4 weeks	5·5	6·2	5·6	oz./sq. ft.
8 weeks	13·5	13·0	13·5	±0·7 ,,
12 weeks	19·8	17·4	18·0	±0·8 ,,
8-12 weeks	6·3	4·4	4·5	,,
Average size—				
0-4 weeks	1·34	1·22	1·17	oz./mushroom
4-8 weeks	1·03	1·01	0·99	,,
8-12 weeks	0·73	0·67	0·68	,,
Whole period	0·96	0·94	0·92	,,

The best average yield from a group of beds treated alike was 1·8 lb./sq. ft. the best single bed gave 2·0 lb./sq. ft.

Table 8. Relation between stack and bed conditions

	Stacks made			
	wet	dry	wet	dry
Beds—	mushrooms/sq. ft.		oz./sq. ft.	
deep tight	21·6	19·4	21·1	18·4
deep loose	14·8	21·9	15·2	19·6
shallow tight	16·1	23·3	16·7	19·3

Deep tightly packed beds gave a slightly higher yield than those made with less compost, whether loosely or tightly packed, but the difference was small and of doubtful significance. It was most noticeable in the last four weeks of the crop.

There is evidence of a relation between stack moisture and bed conditions, surprising because it is the reverse of what one would expect.

It is usually considered that wet compost should be laid rather loosely in the beds to give it a chance to dry out and to avoid producing a soggy mass. In this experiment, however, the wet compost gave the best results when made into deep tight beds ; with dry compost the bed conditions had less effect, but shallow-tight gave most mushrooms without any appreciable difference in crop weight. Even the deep tight beds were only packed by hand and were not trodden down underfoot as is sometimes done to make a really tight bed, so there was little risk of producing the unwanted sogginess.

This is our first experiment on this subject and others will be needed to form general conclusions.

Experiment 18

Twenty four stacks of compost were made in six blocks of four stacks. The experiment was arranged to compare urea and dried blood as sources of nitrogen in M.R.A. compost ; with superphosphate added at the 3rd turn or at filling.

Three casing soil treatments were applied,

14 lb. of carbonate of lime per ton
28 lb. of carbonate of lime per ton
14 lb. of carbonate of lime and 21 lb. of gypsum per ton.

This last mixture was used to find out whether calcium in another sparingly soluble form would have any effect. Each casing soil was applied to all the composts, making a completely factorial design with six randomised blocks of twelve beds.

The results are shown in Tables 9, 10 and 11.

There were no appreciable differences in yield but composts made with urea cropped earlier than those containing dried blood, and the smaller proportion of carbonate of lime also tended to give an earlier first flush.

Conclusions

Urea is at least as good as dried blood for synthetic compost.

The gypsum and superphosphate can equally well be added at filling or at the last turn.

A small excess of carbonate of lime added to the casing soil may have slightly delayed cropping but did not affect yield.

Table 9. Comparison between dried blood and urea

	Dried blood	Urea	s.e.
First pinheads	56	48	±2·6 days from spawning
First picking	62	54	±3·1 ,,
Fruiting—			
4 weeks	12·4	11·5	mushrooms/sq. ft.
8 weeks	23·3	24·2	,,
12 weeks	26·4	28·0	,,
Yield—			
4 weeks	7·9	8·2	oz./sq. ft.
8 weeks	12·8	13·5	,,
12 weeks	14·4	15·4	,,
Average size—			
0-4 weeks	0·63	0·71	oz./mushroom
4-8 weeks	0·45	0·42	,,
8-12 weeks	0·50	0·50	,,

Table 10. Time of adding Activator No. 2

	3rd turn	Filling	s.e.
First pinheads	51	53	±2·6 days from spawning
First picking	58	59	±3·1 ,,
Fruiting—			
4 weeks	11·9	12·0	mushrooms/sq. ft.
8 weeks	23·3	24·2	,,
12 weeks	26·6	27·8	,,
Yield—			
4 weeks	8·0	8·1	oz./sq. ft.
8 weeks	12·9	13·4	,,
12 weeks	14·7	15·1	,,
Average size—			
0-4 weeks	0·67	0·68	oz./mushroom
4-8 weeks	0·43	0·43	,,
8-12 weeks	0·55	0·47	,,

Table 11. Effect of lime treatments of casing soil

carbonate of lime gypsum	14	28	14 21	lb. per ton of soil
First pinheads	49	53	54	s.e. ±1·1 days from spawning
First picking	56	59	60	±2·7 ,,
Fruiting—				
4 weeks	11·0	12·2	12·7	mushrooms/sq. ft.
8 weeks	22·4	24·0	24·9	,,
12 weeks	26·4	27·1	27·8	,,
Yield—				
4 weeks	7·7	8·2	8·4	oz./sq. ft.
8 weeks	13·0	13·2	13·2	,,
12 weeks	14·9	15·1	14·8	,,
Average size—				
0-4 weeks ...	0·70	0·67	0·66	oz./mushroom
4-8 weeks ...	0·46	0·42	0·39	,,
8-12 weeks ..	0·48	0·65	0·55	,,

CHEMISTRY DEPARTMENT

P. B. Flegg

Work on chemical changes in the compost has continued on a restricted scale, but the emphasis is now on the properties and functions of casing soils. A preliminary survey of the methods to be used in the examination of casing soil was given in the last report and during the year soil pH, buffering capacity, water holding properties, structure and stability have been under investigation.

The advisory work of the department has involved the examination of activators, composts, soils and peat samples and in all over 50 enquiries were dealt with.

COMPOSTS

Methods of Analysis

Total nitrogen.	On 20g. fresh compost, Devarda's alloy and dilute acid were used to reduce nitrate, followed by normal Kjeldahl digestion and distillation.
Ammonia-nitrogen.	On 50g. fresh compost, extracted and determined by Richardson's modification of Olsen's method.
Nitrate-nitrogen.	After the Ammonia-nitrogen distillation 2g. Devarda's alloy was added and the distillation was repeated.
Organic nitrogen.	Total nitrogen—(ammonia-nitrogen+nitrate-nitrogen).
Oxalate	Burrows (1950).
Dry matter changes.	Calculated from acid insoluble ash.

RESULTS

Nitrogen changes in urea and dried blood composts

Two stacks of each type of compost (Expt. 18) were sampled at the first turn and again at filling. At each sampling two separate samples were taken from each stack and each sample was analysed separately.

Variations within each stack were found to be much greater at first turn than at filling due to the difficulty of obtaining a representative sample at first turn and to the fact that the compost had not yet been well mixed at this stage.

The coefficients of variation of sample means at the first turn for total nitrogen and ammonia-nitrogen were 7·35% and 7·2% respectively and at filling 3·3% and 3·45%. These figures are in close agreement with those found by Burrows (1950).

It was observed that during composting the urea stacks did not heat up as well as those made with dried blood. Stack temperatures recorded between the 2nd. and 3rd. turn showed the mean temperature of the dried blood stacks to be 56·6° C. and the urea stacks 36·6° C. (s.e. mean ± 2.0). Differences between the stacks may be affected by this as well as by the different nature of the nitrogen source.

The results of analyses are shown in Tables 12 and 13. In the urea composts there was an initial rapid production of ammonia. Ammonia-nitrogen at the first turn was about 40—50% of the total nitrogen present.

This was accompanied by a rise in pH to 9·0. At the end of composting the amount of ammonia-nitrogen was lower and so also was the pH, while the organic nitrogen remained relatively unchanged. Nitrogen losses were comparable with the decrease in ammonia-nitrogen indicating that the ammonia which was produced rapidly just after stacking was lost into the air during the composting period. This is borne out by the observations during composting that the urea composts had a strong smell of ammonia during the early stages, whereas at filling it was barely noticeable. Burrows (1951) attributed the large losses of ammonia from urea stacks to the excessive production of ammonia which is lost before it can be reassimilated by the micro-organisms present in the stack. In these stacks despite the fact that 0·4 to 0·5% ammonia-nitrogen was still present at filling there was no increase in the amount of organic nitrogen as would be expected if reassimilation had taken place.

Table 12. Experiment 18. Nitrogen changes during composting
Dried blood compost (N as % of dry matter at 1st turn)

N distribution	First Turn		Filling	
Stack No.	17	19	17	19
Ammonia—N	0·300	0·250	0·360	0·470
Nitrate—N	·005	·004	·009	·006
Organic—N	2·315	1·966	1·501	1·554
Total N	2·620	2·220	1·870	2·030
pH	7·9	7·6	7·2	7·9

Table 13. Experiment 18. Nitrogen changes during composting
Urea compost. (N as % of dry matter at 1st turn)

N distribution	First Turn		Filling	
Stack No.	18	20	18	20
Ammonia—N	0·960	0·980	0·500	0·400
Nitrate—N	·010	·016	·003	·003
Organic—N	1·500	1·004	1·137	1·017
Total N	2·470	2·000	1·640	1·420
pH	9·0	9·0	7·7	7·4

Standard error of mean total N at 1st turn ±0·14
" " " " " " " Filling ±0·06

The ammonia-nitrogen in the dried blood composts was comparatively low at the first turn and was found to have increased slightly at filling. Organic nitrogen was found to decrease in the dried blood composts showing evidence of a conversion of organic nitrogen to ammonia during composting. The smell of ammonia was not present at the first turn but was definitely noticeable at filling.

Analyses show that despite equal additions of nitrogen at stacking, the urea stacks contained slightly less nitrogen at filling than the dried blood stacks, the chief difference being in the amount of organic nitrogen present.

The percentage of ammonia-nitrogen at filling was approximately the same in both types of compost.

Very little nitrate nitrogen was found either at first turn or at filling, and a more sensitive method of analyses is required for reliable measurement of nitrate changes.

Oxalate

Oxalate was determined on samples of compost from the beds cased with coarse, mixed and fine soil (Experiment 16). It was probable that conditions in the compost varied with the type of casing soil, more aerobic conditions being found under the coarse soil than the fine. Burrows (1949) has suggested the possibility that oxalate is produced under conditions of reduced aeration and plentiful food supply. The results obtained are given in Table 14, and are useless from this point of view because of the complicating effect of density of mycelium, yield and the presence of other micro-organisms. However, there is a rough correlation between oxalate and density of mycelium at the time of sampling. In view of the large number of inter-related factors that appear to affect the oxalate content of the compost, interpretation of results is very difficult and this line of investigation is being discontinued.

Table 14. Oxalate % at end of cropping

Casing soil	Oxalate %	Yield/sq. ft. No.	Yield/sq. ft. Oz.	Notes on compost
Coarse	2·14	17·5	32·0	mycelium run good verdigris present
	2·62	19·6	33·9	,,
Mixed	0·0	3·4	9·1	very little mycelium
	2·49	20·8	27·5	mycelium run good verdigris present
Fine	0·0	0·8	2·2	very little mycelium
	1·24	5·9	10·6	mycelium run good in parts

Manurial Value of Spent Mushroom Composts

Spent composts from several sources have been analysed and the effect of differing composting times and of several nitrogen sources upon the manurial value of the spent compost, in terms of nitrogen, phosphorus and potassium has been examined. The results have been published more fully elsewhere, Flegg (1952). The length of composting period does not appear to have an appreciable effect upon the finished product, but the source of nitrogen used in synthetic composts may be reflected in the final composition of the spent compost. Of the materials used as a source of nitrogen dried blood (M.R.A. activator) produced spent compost with the highest nitrogen content. Using urea, the nitrogen content was found to be much lower ; the initial nitrogen content of the composts was the same.

The presence of soil in the spent compost generally held to be a disadvantage may be beneficial when the compost is applied to light sandy soils, improving texture and increasing drought resisting properties of the soil.

Table 15 summarises the approximate comparative values of farm yard manure, spent compost alone and spent compost-soil mixture.

It has been shown previously (M.G.A. Bulletins 11 and 21) that spent horse manure compost can be used successfully as a manurial supplement. Spent M.R.A. synthetic compost also has a definite manurial value and compares favourably with farmyard manure.

Table 15. Typical Manurial Values

	N	P_2O_5	K_2O
	lb. per wet ton		
Farmyard manure	12	5	12
Spent horse manure compost (excluding soil)	17·5	6	20
Spent horse manure compost (including soil)	8·8	3	10
M.R.A. synthetic compost (excluding soil)	26·5	13	9
M.R.A. synthetic compost (including soil)	13·2	7·5	4·5

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CASING SOIL

R. L. Edwards and P. B. Flegg

Although some of the functions of a casing soil are still uncertain it is probable that a fairly high degree of porosity to air is needed in a good casing soil. Microbial respiration in the compost layer beneath the soil is considerable and in order that there should be a sufficient supply of oxygen for the growing mushroom mycelium it must be possible for a considerable interchange of gases, mainly oxygen and carbon dioxide, to take place.

Some interchange of gases may occur at the sides and bottom of some kinds of bed, but this is probably insufficient and much of the interchange of gases takes place through the casing soil ; in beds laid on concrete, which usually give quite satisfactory results, all the gaseous exchange must do so.

The results of Experiment 16 in which coarse, mixed and fine casing soil was used, show conclusively that the soil with large aggregates gave a much better yield than the mixed or the fine. The finely sieved soil and therefore of reduced permeability gave the lowest yield. See Cropping Experiments, pp. 9 to 11.

The permeability of the soil layer may also be reduced if during the cropping period the soil tends to lose its structure and " pans " down. This can happen as a result of repeated watering. Several cases of soils which form a " pan " after a few waterings have been reported by growers and it is claimed the yield was much reduced.

Thus from growers' observations, direct and indirect experimental evidence, the permeability of the soil layer to gases appears to have an important effect upon yield. The permeability of the soil layer depends largely upon the porosity of the soil at casing, i.e. degree of lumpiness and packing, and upon whether the soil structure is stable enough to withstand the conditions to which it is subject on the beds.

Principal factors likely to affect the structure of the soil

1. Original Structure and Stabllity

The main cementing agents acting in the soil in this country are dehydrated clay colloids and some organic materials. The type of soil aggregates present in the soil will affect their subsequent behaviour under mushroom growing conditions.

In clay subsoils which are commonly used as casing soils the aggregates are cemented mainly by dehydration of the clay colloids ; the greater the dehydration the greater the stability. The disintegration of this type of aggregate can be brought about in two ways. Firstly, wetting involves unequal swelling causing pieces to fall off, and also traps air within the aggregate which causes disruption as the pressure of the trapped air exceeds the cohesion of the particles. Secondly, dehydration affects the colloidal clay cementing agent and the aggregates lose their stability and break down. Allowing a clay subsoil to dry out before casing increases its resistance to breakdown by watering.

Aggregates cemented by certain types of organic matter are generally more resistant to breakdown by these processes. Organic matter can produce aggregates in several ways. The formation of a clay-humus complex, the action of metabolic products of several micro-organisms and the presence of roots, bacteria and filamentous fungi can all cause the production of aggregates. The modes of action of these various ways in which aggregates are formed is not yet clearly understood nor are their effects upon stability of the aggregates fully investigated. However, aggregates involving the presence of organic matter occur in soils near the surface. These soils are not sterile, containing food material for micro-organisms, and may contain organisms harmful to the mushroom. This may be overcome by suitable treatment but methods of sterilisation involving high temperatures will have an adverse effect upon the soil aggregates.

2. Presence of mushroom mycelium. This permeates the soil before and throughout the cropping period. It is known that several soil fungi have an aggregating effect upon the soil by the production of gumlike substances which act as cementing agents. It is also to be expected that the mushroom mycelium will have a mechanical binding effect upon the soil.

3. Repeated Watering. Regular watering up to several times a week has a mechanical breaking down effect. The type of rose used and water pressure may be found to be important. The relatively high temperature in the house combined with regular watering cause a wetting and drying cycle which also tends to disintegrate the soil aggregates.

METHODS

Soil Structure

Wet sieving was found to be satisfactory as a measure of the aggregation of a soil sample. The method used was described in last year's Report. Sampling was found to be very important and a system of quartering was used to obtain a representative sample.

$$\text{Degree of Aggregation} = \frac{\text{dry weight of aggregates} > 2 \text{ mm.}}{\text{dry weight of sample}} \%$$

Soil Stability

An indication of the stability of soil aggregates was obtained by immersing a number of aggregates in trays of water and noting the degree of breakdown by slaking in a given time. The aggregates were classified as (1) intact ; (2) partly disintegrated or (3) completely disintegrated. The method is arbitrary and a certain amount of personal judgment is involved, but the results obtained appear reasonable and reproducible for one observer.

Water Holding Properties

The suction method for the determination of the Moisture Equivalent, Maximum Moisture Holding Capacity and Pore Space devised by Tinsley and described in the last Report has been improved. Previously a water moat was used to obtain an airtight seal during suction, but it was found that water from the moat percolated into the soil causing errors. Replacement of the water moat by mercury greatly increased the accuracy ; the standard error of the mean was reduced from $\pm$ 0·42 to $\pm$ 0·17.

For the calculation of the Total Pore Space by this method it is assumed that the volume of water present when the sample is waterlogged occupies the pore space. However, water held with a tension greater than pF 4·2 the Wilting Point, is not available for use by plants. A more accurate measure of the Pore Space available in the soil for holding water which can be utilised by plants is obtained by taking into account this unavailable water. Attempts have been made to measure the moisture content of soil samples at pF 4·2 by placing them in an atmosphere of 99% relative humidity, in equilibrium with saturated calcium sulphate solution, for 7 days. Values obtained in this way give a reasonable estimate of the Wilting Point, but Tinsley (1951) has found that even after 44 days equilibrium had not been reached. Work on the possibility of obtaining a value for the Wilting Point using high humidities is being continued.

Mycelium in the Soil

In order to observe the effects of certain treatments and to obtain information on the growth of mycelium in the soil, a quantitative method of measuring the amount of mycelium present in a sample of soil is required. This has been done by means of the Walkley & Black method for estimating soil organic matter, care being taken to remove all compost from the soil.

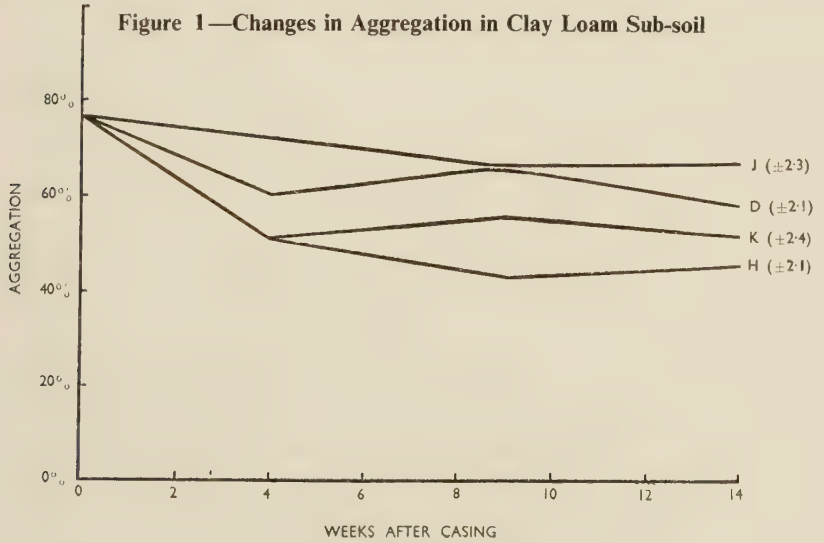
RESULTS

The effect of mycelium on soil structure on the bed

In order to follow the changes in soil aggregation during the cropping period samples of soil were taken from the pots removed during the course of the Pot Experiment (see p. 31). Pots receiving treatments D, E, F, G, H, J and K, were sampled and thus the effect of the mycelium on three types of soil, and on the clay loam subsoil with four different watering treatments, could be observed.

The clay loam subsoil at casing had a good lumpy structure, aggregation being 76·7 ± 1·9%. The changes in the state of aggregation of this soil under the four watering treatments are shown in Fig. 1. It

Figure 1—Changes in Aggregation in Clay Loam Sub-soil



will be noticed that there was considerable breakdown of the structure of the soil during the first four weeks in the pots which were heavily watered (H & K). Mycelium was observed to be entering the soil at the end of the fourth week ; further breakdown was arrested despite the continuation of heavy waterings. There was an indication in pots receiving treatments D, H and K, that aggregation was increased by the presence of mycelium. However, the increases were not statistically significant.

These changes in aggregation do not appear to be related to the number or weight of mushrooms picked.

Changes in the aggregation of the soils of poor initial structure are shown in Fig. 2. The clay loam E showed an increase in aggregation after four weeks, which was maintained up to nine weeks. A similar effect was observed in the sandy soil with and without peat. These two soils contained no stable aggregates at casing but after nine weeks lumps of soil held together by mycelium were definitely noticeable.

The Effect of Watering upon Soil Structure on the Bed

Analysis of the samples of clay loam subsoil on the pots for organic carbon show an increase of only 1·2% to 3·5% after 4 weeks compared with 15% at the end of the experiment. On the basis of these figures and from observation during the experiment it is assumed that the mycelium can have had little or no effect upon the soil structure during the 4 weeks immediately after casing. Fig. 3 shows the degree of breakdown with the mean weight of water applied at each watering. As expected the greater the amount of water applied the greater was the breakdown. The degree of disintegration tended to reach a maximum when the quantity of water applied at one time reached about 16% of the weight of dry soil.

The effect of differing levels and rates of watering upon the clay loam subsoil was examined more thoroughly by placing the air dried soil, sieved so that the size of lumps was between $\frac{1}{4}$″ and $\frac{3}{4}$″, in rectangular plastic trays 6″ × 8″ and 1″ deep. 750 g. of soil were placed in each tray and the soil was watered as shown in Table 16. The normal rate of watering our clay loam subsoil is about 60 gallons/1,000 sq. ft. This quantity and the times of watering vary according to conditions. The

Table 16. Soil watering treatments

Tray	Rate of watering % of air dry weight of soil Weekly total.	Application	Equivalent rate of watering per 1,000 sq. ft.
B1	20%	20% once weekly	125 gallons once weekly
B2	20%	10% twice weekly	$62\frac{1}{2}$ gallons twice weekly
B3	10%	10% once weekly	$62\frac{1}{2}$ gallons once weekly
B4	10%	5% twice weekly	$31\frac{1}{4}$ gallons twice weekly
	15%	15% once weekly	$93\frac{3}{4}$ gallons once weekly

All treatments were applied for 4 weeks

Figure 2—Changes in Aggregation in Soils of Poor Structure

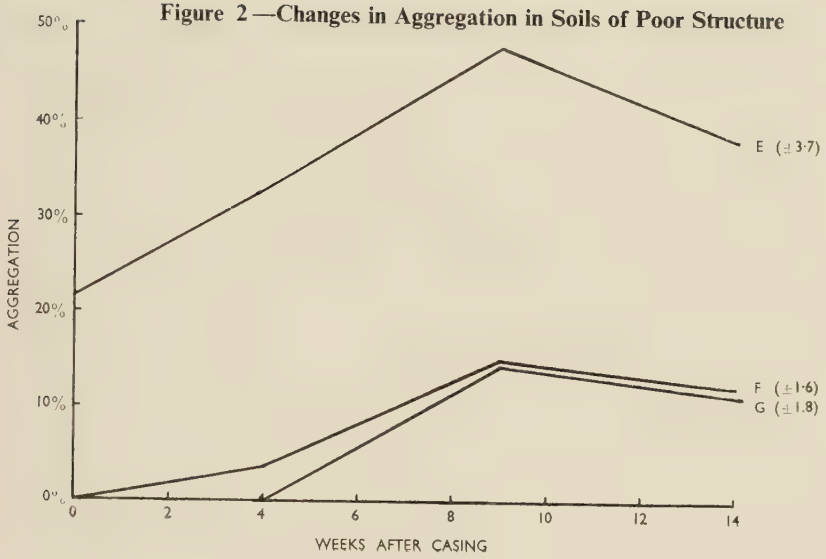
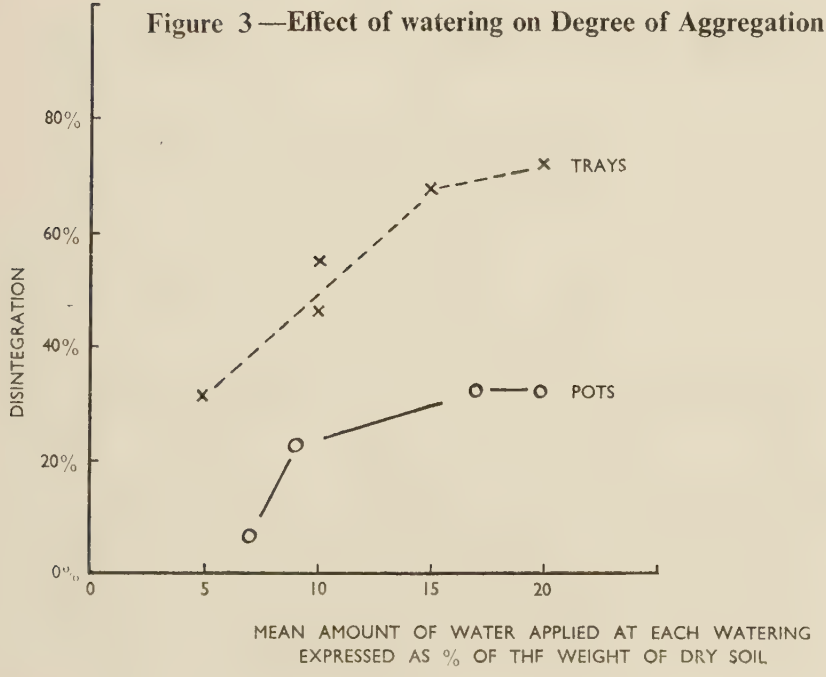


Figure 3—Effect of watering on Degree of Aggregation



effect on the soils is shown in Fig. 4 and 5 which show the top and under-surfaces of these layers of soil after treatment. The effect of heavy watering in breaking down the lumps of soil is strikingly obvious. After 4 weeks the soils were wet sieved to measure the extent of breakdown.

The results of this experiment are shown in Table 17.

Table 17. % Aggregation (2.0 mm.) of Clay Loam Subsoil after watering (means of 6 determinations)

Treatment	10% watering per week		15% watering per week		20% watering per week	
	Single Watering	Two Waterings	Single Watering	Two Waterings	Single Watering	Two Waterings
% Aggregation	52·9	67·5	30·8	—	26·3	45·5

Standard Error of difference between means ± 3·74

Waterings with 20% and 15% of the air dry weight of the soil at 7 day intervals had an equal effect and caused much greater soil breakdown than a single weekly watering with 10%. This difference is significant ($P < ·01$). Also it was found that the heavier watering ($62\frac{1}{2}$ gallons upwards per week) caused much less breakdown if the water was applied in two waterings per week instead of once a week ($P < ·01$). As was found with the clay loam on the pots, breakdown was not increased appreciably (See Fig. 3) by watering at rates higher than 90 gallons per 1,000 sq. ft. (15% of the weight of dry soil) per week, under the conditions of these experiments.

The Effect of Mycelium on Stability

It was noticed during wet sieving that aggregates permeated with mycelium did not take up water readily when wetted. This was previously reported by Pizer and Leaver (1947) and Pizer (1950) has suggested the use of wetting agents when watering mushroom beds.

Stability tests have been made by immersion in 0·5% solutions of surface active agents as well as in water. Soil well permeated with mycelium (A) was taken from a series of beds which had cropped well and was compared with samples from beds which had produced no crop and with little or no mycelium present in the soil (B). All samples had received the same watering treatment.

Lumps of approximately the same size were taken from the air dried soils and 5 lumps of each soil were placed in trays containing water and solutions of cationic, anionic, and non-ionic surface active agents. Table 18 shows the typical state of breakdown of each of these soils after 30 minutes. There was no noticeable difference between aggregates immersed in water and those in surface active solutions but taking all the trays together the soil with little or no mycelium present disintegrated to a much greater extent than the soil permeated with mycelium. The

Figure 4. Surface of soil after different watering treatments

Figure 5. Under-surface of soil after different watering treatments

result was much the same after 14 hours immersion. This effect was reproduced (Table 19) using 10 lumps of each soil in water only. Thus the presence of mycelium in the soil aggregates had a definite effect, increasing the stability of the soil aggregates to water.

Table 18. Effect of mycelium upon aggregate stability

State of aggregates after 30 minutes

State of Aggregates	Water		Anionic solution		Cationic solution		Nonionic solution		Total	
	A	B	A	B	A	B	A	B	A	B
Intact	3	0	5	0	2	0	2	1	12	1
Partly disintegrated	2	3	0	3	3	3	3	4	8	13
Completely disintegrated	0	2	0	2	0	2	0	0	0	6

A = aggregates with mycelium
B = aggregates with no mycelium.

Table 19. Condition of 10 aggregates after 30 minutes in water

	A Mycelium present	B Mycelium absent
Intact	5	1
Partly Disintegrated	3	4
Completely Disintegrated	2	5

Improvement of the Stability of Soils

Increased water-stability can be imparted to soil aggregates by the addition of water-proofing materials. McCalla (1945) has reported that waxy and resinous materials increase the stability of soils. The use of resinous materials for water-proofing soils for constructional purposes has been described by Clare (1949). Such methods of improving the stability of soils may not be suitable for application to mushroom casing materials because of the requirement of a high water holding capacity ; also the effects of the materials used on the mushroom mycelium are unknown. Van Bavel (1950) has demonstrated the use of volatile silicones in increasing the stability of soil, but the use of silicone-treated soils in the field has not yet been reported. The incorporation of potassium silicate into the top 3″ of soil has been found to induce remarkable improvements in stability of aggregates to rain and compaction (Dutt, 1948). In this case plant crops were used and improvements in growth and yield were recorded. The effect of treating soil with sodium silicate has been studied. The soil was soaked by capillary action with a 5% solution of sodium silicate and was then air dried. Samples were similarly treated with water and with a solution of anionic detergent for comparison. The treated soil

was then slaked by sudden immersion in water. The soil was allowed to remain immersed for 90 minutes and was then wet sieved. Table 20 shows the aggregate analysis of the soils after treatment.

The silicate treated soil showed a significantly higher % aggregation than the water ($P < \cdot025$) and detergent ($P < \cdot01$) treated soils. More information is required on this kind of soil treatment and its effect on the mushroom.

Table 20. Effect of soil treatment upon water-stability

Treatment	% aggregation after treatment and subsequent slaking means of 4 determinations	
Water	53·24%	±2·2
Anionic Detergent 5·0% solution	49·55%	±2·5
Na silicate 5·0% solution	67·74%	±2·3

Mycelium in the Soil

Analyses of the organic carbon content of the soils taken from the pots at casing, and 4 and 14 weeks after casing have been made and are shown in Table 21. In the pots cased with the Yaxley clay loam subsoil there was a gradual increase in organic carbon content, due to the mycelium invading the soil. The treatments which produced the greater yields showed the highest increase in organic matter while those which produced little or no yield showed a much smaller increase.

The clay loam (Wisbech) soil which was high in organic carbon at casing showed an increase after 4 weeks, but at the end of the experiment the amount of organic carbon present was slightly below the amount present at casing despite the obvious presence of mycelium in the soil.

The results from the sandy soil with and without peat are more difficult to interpret as this soil contained seeds which germinated during the cropping period thus causing changes in organic matter content not due to the mycelial growth. In these soils however, the highest yielding pots, L and P, showed an increase in the amount of organic carbon while the pots producing a lower yield, M and Q, showed either a slight increase or a loss.

Samples taken from beds cased with coarse, mixed or fine soil (see p. 9) were also analysed at the end of cropping, Table 22. No definite correlation between yield and amount of mycelium was found, though in the coarse and fine soils the highest yielding beds had a higher organic carbon content.

It is not possible to draw definite conclusions from the results obtained, but the possibility of obtaining data on the factors affecting density of growth of mycelium in the soil and the possible effects of organic matter present in the soil at casing by this method is apparent and the work is continuing.

Table 21. Mycelium in the soil as measured by % Organic Carbon

Soil & treatment		% Organic carbon (Walkley & Black values)			
	At casing	Interval from casing 4 weeks	14 weeks	Change inorganic carbon as % at casing	Yield oz./pot
Yaxley clay loam subsoil D	0·581	0·602	0·668	+15·0	3·1
H		0·588	0·656	+12·8	1·8
J		0·604	0·627	+ 7·9	0·0
K		0·602	0·626	+ 7·7	0·4
s.e. means		±0·004			±0·3
Wisbech soil E	2·9	3·03	2·88	— 0·7	3·8
Shropshire soil F	1·33	1·45	1·38	+ 3·7	4·2
L		—	1·58	+18·4	4·3
M		—	1·34	+ 1·1	3·4
Shropshire soil + peat G	2·14	2·16	1·98	— 7·5	3·8
P		1·93	2·18	+ 2·1	4·5
Q		2·49	2·00	— 6·4	3·4
s.e. means		±0·04			±0·3

Table 22. Mycelium in Coarse, Mixed, and Fine Soils

Soil	Organic C. % at emptying	Yield lb./sq. ft.	Actual Cropping period days	Days to 1st picking
Coarse	·688	2·0	91	66
	·755	2·12	100	62
Mixed	·688	0·57	63	69
	·684	1·68	83	84
Fine	·649	0·14	14	106
	·733	0·66	83	70
s.e. mean	±·008			

SOIL MOISTURE REQUIREMENTS IN MUSHROOM CULTIVATION

Pot Experiment. An experiment was arranged to observe the rates of watering and evaporation in several types of soils each having two or three watering treatments, using 8″ plastic plant pots. Enough of these pots could be used to provide sufficient replicates of each treatment. Also the pots were of convenient size for weighing to record daily changes in weight.

The soils used were :—

(1) a clay loam subsoil of good structure with added sand and lime (as normally used on our beds)
(2) a clay loam of poor structure (Wisbech)
(3) a sandy soil with added ashes (Shropshire)
(4) the same sandy soil with ashes and 1 part of peat to 5 parts of soil by volume with 22 lb. of hydrated lime per ton, to neutralise the peat ; Table 26 shows the water holding properties, initial aggregation, and organic carbon content of the soils at casing.

The treatments and arrangement of the blocks are given below. All the pots were placed on one shelf of the house in which cropping Experiment 16 took place and were subject to the same conditions of ventilation, humidity and temperature. The pots were filled in blocks of 3 or 4 to obtain greater uniformity ; the pots in each block were allocated to the various treatments at random in the usual way.

Soils and Treatments

Group 1. 18 blocks.

D. Yaxley soil (1) " normal " watering. 18 pots.
E. Wisbech soil (2) ,, ,, ,,
F. Shropshire soil (3) ,, ,, ,,
G. Shropshire soil plus peat (4) ,, ,, ,,

Group 2. 16 blocks, all Yaxley soil (1).

H. " Kept wet," watered frequently and rather heavily to maintain the soil throughout in what was considered a rather wetter condition than is normal.
J. " Kept dry," watered about as frequently as in H, but rather lightly to maintain the soil as nearly dry as was possible without completely stopping fruiting.
K. " Wet and dry," watered less frequently, but heavily, to obtain an alternation of wet and dry conditions in the soil.

Group 3. 12 blocks.

L. Shropshire soil (3) " kept wet."
M. Shropshire soil (3) " kept dry."
P. Shropshire soil with peat (4) " kept wet."
Q. Shropshire soil with peat (4) " Kept dry."

There was naturally a considerable element of personal judgment in applying these treatments, but the weights recorded show that the general scheme was followed.

Blocks of pots were removed at intervals for sampling and analysis. It was hoped to obtain estimates of dry matter loss so that the total losses of weight could be corrected for this factor, but the results proved too

variable. However, dry matter losses were considerably smaller than the observed fluctuations in moisture, and did not contribute large errors.

All pots were weighed at approximately 2 day intervals and losses in weight, watering, picking and any other changes were recorded. Each pot was filled with $2\frac{1}{2}$ lb. of wet compost (73% moisture) from a large stack, and placed in position on the shelf in the house. The pots were peak heated, spawned and cased at the same times as the beds. Spawning took place one week after filling and the pots were cased 19-23 days after filling. The pots were watered 8 days after casing was completed. This was early compared with general practice, but the pots appeared to have dried out excessively during peak heating, and further drying might have damaged the spawn.

Samples were taken for analysis at casing and again 4, 9 and 14 weeks after casing.

Results

The cropping results are given in Tables 23-25 together with details of watering, appearance of pinheads, etc.

All the soils tested produced mushrooms under at least one treatment in reasonable amounts—3 oz./pot is equivalent to 168 lb. mushrooms per ton of wet compost, or 9 oz. per sq. ft. This is low on a bed area basis, which was to be expected with such a small amount of compost (equivalent to 7·5 lb. per sq. ft., or 300 sq. ft. per ton), and the unfavourable shape of the pots. The mushrooms obtained from the clay loam subsoil were of good quality, but from the soils of poor structure the mushrooms were small, thin stalked, and inclined to be scaly.

In the clay soils the appearance of the first pinheads was preceded by mycelium penetrating to the surface of the soil, this did not happen with the sandy soils where generally there was little sign of mycelium on top of the soil throughout cropping.

The several watering treatments produced marked differences in cropping performance and for a more general interpretation of the results the moisture contents of the soils have been converted to pF values in order to relate watering with water holding capacity. The effect of the heavy waterings on the compost beneath appeared to be slight. A few of the heavily watered pots had a layer about 2″ deep at the bottom of the pot which was saturated.

The moisture range in each soil was determined by use of the day to day gains and losses and moisture % of the soils found at the four sampling times, from which we could estimate the mean maximum and minimum moisture contents of the soils under the several treatments.

The moisture content of each soil was determined at three points on the pF scale. The suction method (already described) was used for pF 0 and 2·7. The wilting point for plants F 4·2, was found by exposing the soil to air at a relative humidity of 99% (over saturated calcium sulphate solution) under reduced pressure for 7 days. The pF graphs obtained are only approximate as many more than three points are required for an accurate pF curve, but they should be sufficient to estimate the approximate working pF range in the pot soils.

Table 23. Cropping on four soils with " normal watering "

Days from casing to—	Yaxley D	Wisbech E	Shropshire F	Shrop. + peat G
Mycelium visible	25	21	—	—
First pinheads	58	44	41	51
First picking	77	56	52	56
Watering treatment—				
Total water oz./pot	42	37	37	38
No. of waterings	14	12	11	11
Crop—				
Mushrooms per pot	3·1	8·8	12·4	10·8 ± 1·0
Oz. per pot	3·1	3·8	4·2	3·8 ± 0·3
Moisture range,				
% of dry soil	12—21	14—25	9—18	7—18
pF range	3·9—3·2	3·9—3·4	3·7—2.9	4·0—3·3

Table 25. Cropping on Yaxley soil

Days from casing to—	" kept wet " H	" kept dry " J	" wet and dry " K
Mycelium visible	25	35	25
First pinheads	62	—	—
First picking	—	—	—
Watering treatment—			
Total water oz./pot	47	22	36
No. of waterings	10	10	6
Crop—			
Mushrooms per pot	1·4	0	0·4
Oz. per pot	1·8	0	0·3
Moisture range,			
% of dry soil	12—28	10—16	7—26
pF range	3·9—2·6	4·1—3·6	4·3—2·8

Table 24. Cropping on Shropshire soil

Days from casing to—	no peat " kept wet " L	no peat " kept dry " M	with peat " kept wet " P	with peat " kept dry " Q
Mycelium visible	—	—	—	—
First pinheads	47	41	40	40
First picking	60	52	50	48
Watering treatment—				
Total water oz./pot	48	27	48	27
No. of waterings	11	11	11	11
Crop—				
Mushrooms per pot	7·5	11·9	14·0	14·3 ± 1·4
Oz. per pot	4·3	3·4	4·5	3·4 ± 0·4
Moisture range,				
% of dry soil	—	9—18	17—31	9—18
pF Range	—	3·7—3·0	3·4—2·5	3·9—3·3

Figs. 7, 8, 9 and 10 show the pF curves of the four soils used and the range of moisture obtained in each treatment. Fig. 7 shows that drying of the Yaxley soil above pF 4·0, slightly wetter than the plant wilting point, even for part of the time, reduced the yield to practically nothing in treatments J and K. Stroma developed in all of the pots when this soil was " kept dry " (pF range 4·1—3·6).

" Normal watering " (pF range 3·9—3·2) gave the best yield on this soil and watering heavily enough to raise soil moisture content above the moisture equivalent when it was " kept wet " (pF range 3·9—2·6) reduced the yield. Similar liberal watering had not the same effect in the sandy Shropshire soil with peat (Fig. 10). The maximum yield was obtained from this soil " kept wet " (pF range 3·4—2·5). When this soil with or without peat was " kept wet " (L and P) the yield was significantly greater than that obtained from the " kept dry " treatments M and Q ($P = \cdot01$). It was not possible to estimate the pF range on the L pots but in this case the yield was the same as on the same soil normally treated (F), (pF range 3·7—2·9).

There is insufficient information as yet to define an optimum moisture range for casing soil within close limits, but it has been found under our conditions that drying out to and beyond the plant wilting point considerably reduces the yield, and on one soil completely prevented fruiting. Keeping the soil within a moisture range just below the wilting point (treatment J) caused stroma and the few pinheads that did form died. The alternate wet and dry treatment (K) did not produce stroma and a few pinheads developed fully. The upper limit of watering, however, appears to be complicated by its effect on the permeability of the soil to air at high moisture contents, but is in the region of the moisture equivalent. Watering to high moisture levels may cause deterioration of soil structure and this also reduces the permeability of the soil to air.

The pots cased with clay loam subsoil and " kept dry " were later watered more heavily (normal watering), 4 pots being covered with bell jars with a small opening at the top, and 4 left uncovered. Despite the previous treatment and a period of drying out before the heavier watering treatment started, the mycelium soon grew normally. On the uncovered pots, pinheads appeared 5 days after the first medium watering and mushrooms were picked after another 11 days. 20 mushrooms weighing $15\frac{3}{4}$ oz. were produced. The covered pots did not crop so well ; pinheads appeared after 11 days on 3 out of the 4 pots ; 8 mushrooms weighing $9\frac{1}{4}$ oz. were produced but 5 of the mushrooms weighing $6\frac{1}{4}$ oz. grew outside the bell jar.

Thus drying out did not impair the cropping potentialities of the pots ; but restricting ventilation and evaporation by bell jars delayed and reduced fruiting.

The rates of evaporation and dry matter loss from the pots during the cropping period have been studied, but no differences could be detected between the period of early spawn growth and that of actual growth and development of fruiting bodies. The daily loss of weight varied considerably, being generally greater on the wetter pots than on the dry (0·7—0·2 oz./pot) and also greater just after watering than when the soil had dried out. The results although somewhat variable showed the

effect of changes in conditions ; the period during which the adjoining house was peak heated with consequent rise in temperature in the cropping house was clearly shown.

These observations on the day to day evaporation of water from the casing soil, and its relation to fruiting are still being worked out in more detail.

It should be noted that the figures for pore space of 4 soils, given in Table 26, are on soil after passage through a 2 mm. sieve, not in lump form as on the bed. They represent an inherent property of the fine soil particles and the corresponding values for these soils on the beds may be different according to size of lumps and the effect of screening and watering on them.

Table 26. Moisture holding and other characteristics of soils used in pot experiments

	Clay loam subsoil (Yaxley) with sand and lime	Clay loam (Wisbech)	Sandy soil with ashes (Shropshire)	Sandy soil with ashes and peat : lime
Maximum Water Holding Capacity pF 0	% 41·8	% 55·5	% 54·6	% 61·6
Moisture Equivalent pF 2·7	26·95	41·1	20·65	27·50
Wilting Point pF 4·2	8·36	6·61	3·30	3·70
Total Pore Space	48·65	54·91	49·50	53·12
Total Capillary Pore Space	31·25	41·0	18·67	23·75
Total Non-capillary Pore Space	17·4	13·91	30·88	29·37
Organic Carbon, Walkley-Black values	0·58	2·90	1·33	2·14
Aggregation % (>2 mm.) at casing	76·7	23·67	0·0	0·0

Figure 7—Approximate Moisture Range on pots cased with Yaxley Clay Loam Sub-soil

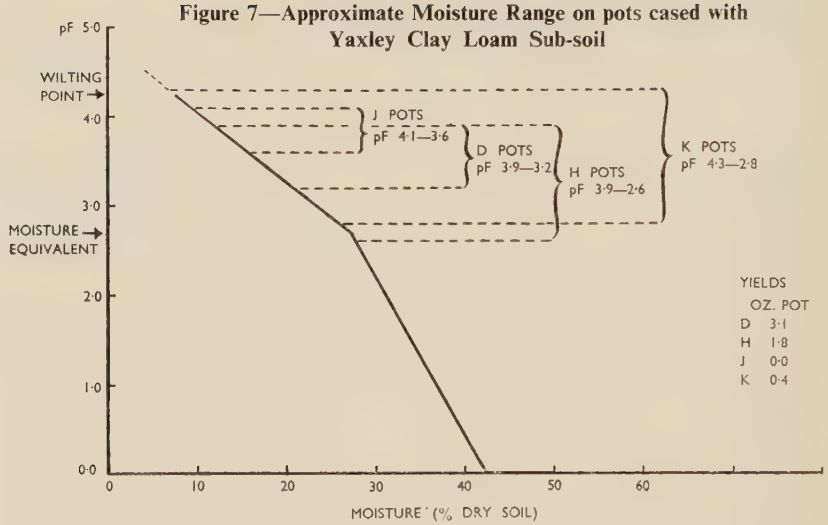


Figure 8 —Approximate Moisture Range on pots cased with Wisbech Soil

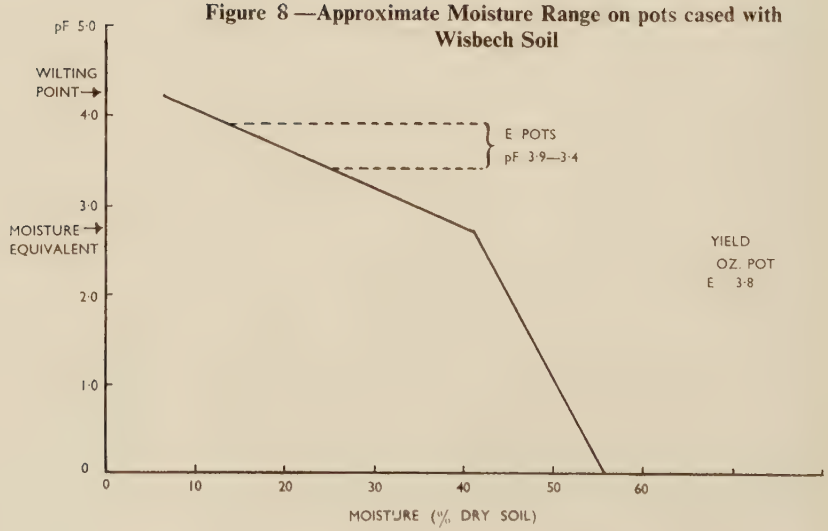


Figure 9—Approximate Moisture Range on pots cased with Shropshire Soil

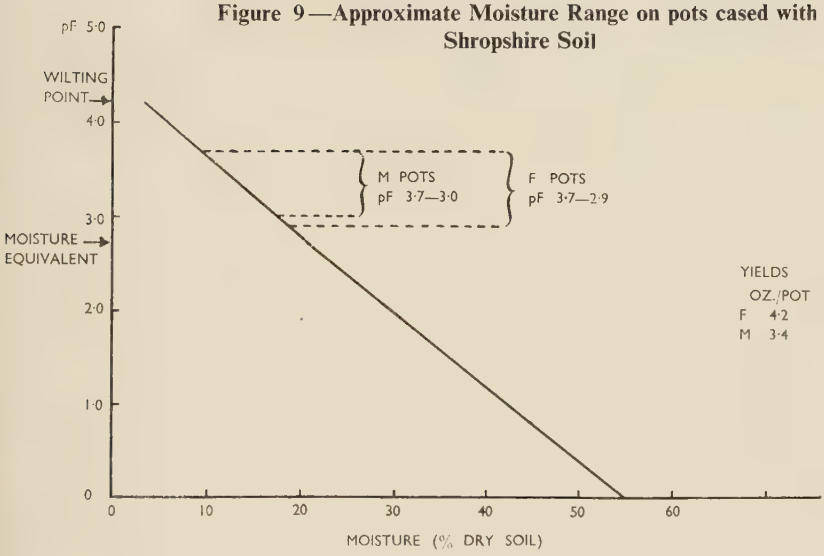
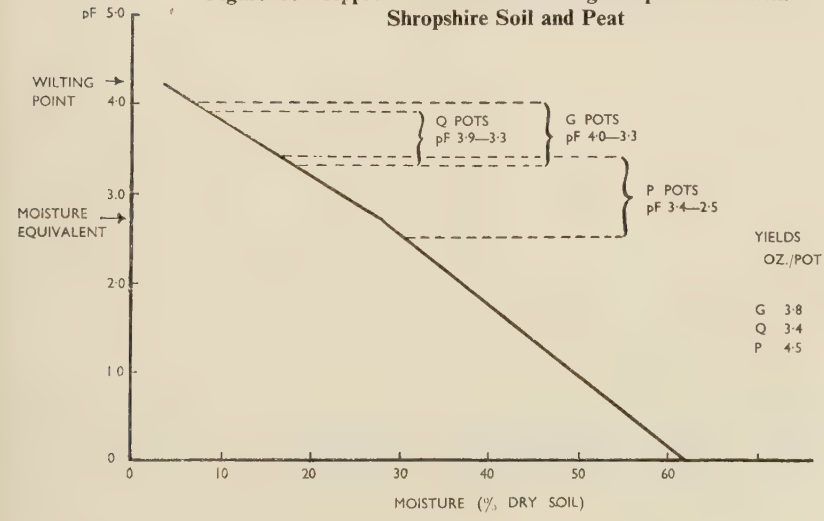


Figure 10—Approximate Moisture Range on pots cased with Shropshire Soil and Peat



Soil pH and Calcium

Lambert and Humfeld (1939) found by artifically altering the pH of a casing soil which was naturally 6·0 that any pH value between 5·5 and 8·0 gave satisfactory yields of mushrooms. Excessive amounts of hydrated lime were found to be harmful, reducing the yield, but equivalent quantities of calcium carbonate were found to be just as effective in neutralising the soil and there was practically no danger of injuring the crop by the addition of excess. Acid soils gave lower yields but there was some doubt whether the low pH in itself (4·4) or the sulphuric acid used to produce the acidity caused the reduction in yield. However, when naturally acid soils were used and produced poor yields, the addition of hydrated lime was beneficial.

Later Chapuis and Courtieu (1950) tested soils with pH ranging from 4·5 to 8·9. They found that the limits for good yields were between 7 and 8·5 with an optimum between 7·2 and 8·2. They also found that excessive alkalinity was undesirable.

Experiment 16 in which four liming treatments were used is described in the Cropping Report, p. 11. Table 27 shows the original pH of these soils and also at 15 and 21 weeks after casing. The changes in soil pH in the pot experiment are shown in Table 28. The initial pH values of the soils treated with hydrated lime in Experiment 16 were higher than those recorded by Lambert and Humfeld, but these workers were of the opinion that the true pH values of their soils were much higher than the values reported, due to the limitations of the method of pH measurement then in use.

Although the pH of the unlimed soil in this experiment was 7·5, within the optimum range, the addition of either hydrated lime or carbonate of lime to the soil resulted in higher yields.

Where equivalent amounts of hydrated lime (20 lb.) and carbonate of lime (27 lb.) were added, the highest yield was obtained from the soil treated with carbonate of lime. The initial pH of this soil was 7·8 whereas 20 lb. of hydrated lime raised the pH to 12.3. It can be seen from Tables 27 and 28 that on the pots the soil pH dropped from 12·4 to 7·8—7·9 within 4 weeks after casing and it was below 8·0 on the beds when measured 15 weeks after casing. It is reasonable to assume that for most of the cropping period the pH of the soil on the beds, whatever the liming treatment, was below 8·0.

These results confirm previous observations that carbonate of lime in large amounts, up to 27 lb. per ton, is not harmful and that a high initial pH is undesirable. A high initial pH is likely when soil is treated with hydrated lime shortly before casing. This could be avoided by storing the soil for some weeks after treatment with hydrated lime until the pH has dropped to about 8·5.

The satisfactory yield obtained with Yaxley clay loam containing 27 lb. of carbonate of lime per ton (pH 7·8) suggests that it is the high pH due to over-liming which is sometimes harmful when hydrated lime is used. 27 lb. of carbonate of lime is equivalent in neutralising power to 20 lb. of hydrated lime, which would raise the pH to about 12·0. This confirms Lambert & Humfeld's findings that high amounts of carbonate are not harmful.

pH measurements have been taken during cropping on the soils of this experiment and on the soils from the pot experiment. Table 28 shows that although the initial pH of the Yaxley clay loam on the pots was high it had dropped in all cases to 7·9—7·8 within 4 weeks after casing. The pH on all the beds for most of the cropping period is therefore no higher than 8·0—8·5 whatever the liming treatment and it would seem that it is the high initial pH which is undesirable.

Table 27 showing the pH readings from the beds under the four liming treatments W, X, Y and Z shows some complicating effects due to " filling in " with fresh soil due to cropping, resulting in increases in pH from 15 weeks to 21 weeks. In general it can be seen that despite large differences in initial pH, at emptying the pH on all beds tested was between 7·35 and 8·3 and that the initial pH was reflected to a small extent in the pH of the beds 21 weeks after filling.

Table 27. pH of casing soil from beds during cropping
(Treated soil was used to fill in holes after picking)

Treatment	Original pH	15 weeks after casing pH	21 weeks after casing pH
W. No lime	7·5	7·4 7·5 — —	7·6 7·5 7·5 7·5
X. 5 lb. hydrated lime	10·35	7·7 7·5 — —	7·8 7·6 7·8 7·65
Y. 20 lb. hydrated lime	12·3	7·9 7·75 — —	8·0 7·8 8·3 7·7
Z. 27 lb. .... carbonate of lime	7·8	7·5 7·5 — —	7·4 7·4 7·4 7·35

In the pots cased with Yaxley clay loam the fall in pH was not connected with yield ; D pots which gave the highest yield of this group showed the lowest fall in pH. The greatest fall in pH occurred in the K series of pots which were subjected to the " wet and dry " treatment.

pH changes during cropping

No extra soil was added to the pots during cropping and the pH readings from this source are not complicated by additions of fresh soil, probably of higher pH than that already present. Table 28 shows that there was a gradual fall in pH during cropping, the greatest fall occurring in the Wisbech soil.

Table 28. pH of casing soil from pots. No soil added during cropping

Soil type	Treatment	Original pH	4 weeks pH	14 weeks after casing pH
Yaxley	D	12·4	7·8	7·7
Clay loam	H	12·4	7·8	7·5
	J	12·4	7·9	7·65
	K	12·4	7·85	7·25
Wisbech soil	E	7·8	7·05	6·25
Shropshire soil	F	7·65	7·50	7·25
	G	12·4	7·95	7·4

Table 29. pH of casing soil from beds. Yaxley clay loam—mixed, fine and coarse treatments. Treated soil was added to fill in during cropping

Treatment	Original pH	15 weeks pH	21 weeks after casing pH
Fine		7·7	7·6
		7·85	7·8
	12·6	—	7·6
		—	7·6
Mixed		7·65	7·4
	12·4	—	7·7
		—	7·4
Coarse		7·7	7·6
	10·8	—	7·7
		—	7·4

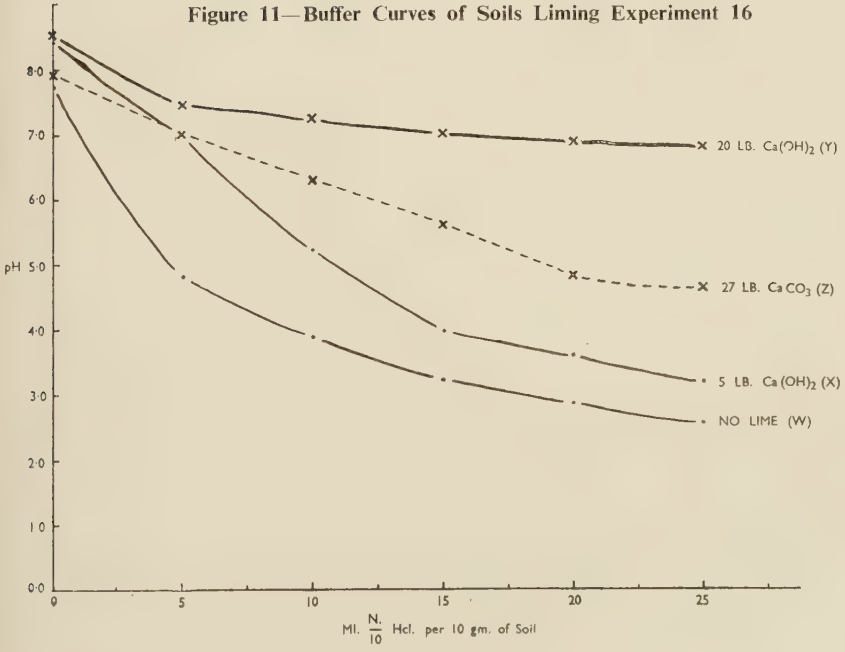
The pH measurements on the beds on which coarse, mixed and fine grades of soil were used show that the pH dropped from high initial values to between 7·4 and 7·8. As the initial pH values were all high there is no reflection of initial pH in the final pH and despite large differences in the yields from these three soil treatments the final pH values of the soils at emptying show little or no difference (Table 29).

The difference in initial pH between these soils is thought to be due to the fact that the soil was limed before sieving and consequently more lime passed into the fine and mixed fractions than remained in the coarse fraction.

Table 30. Effect of start of cropping on pH of casing soil

	Early start Interval from casing			Late start Interval from casing	
Bed No.	15 weeks pH	21 weeks pH	Bed No.	15 weeks pH	21 weeks pH
W.69	7·5	7·5	W.43	7·4	7·6
X.70	7·5	7·6	X.38	7·7	7·8
Y.62	7·75	7·8	Y.37	7·9	8·0
Z.67	7·5	7·4	Z.40	7·5	7·4

Figure 11—Buffer Curves of Soils Liming Experiment 16



The effect of the time of commencement of cropping upon pH has been studied. Table 30 gives a series of pH readings from beds which started early and some which started late. There is no difference in the soils of low initial pH treatments W and Z, but with a high initial pH the readings at 15 and 21 weeks are lower when cropping started early than when it started late. The value of these readings is doubtful as they show a rise in pH from 15 to 21 weeks, probably due to the effect of soil being added to the beds during this period. The pH of the soil used for " filling in " was measured and was higher than the pH of the soil on the beds. This in itself shows that the effect of watering, mycelial growth and other factors lower the pH of the soil more rapidly than if the soil were left untouched in a heap.

The effect of the addition of lime on the buffering capacity of the Yaxley clay loam is shown in Figure 11. Buffer curves for soil treatment, W, X, Y and Z are shown. The addition of hydrated lime increases the buffering capacity considerably. Soil Z treated with 27 lb. carbonate of lime per ton is not so well buffered as soil Y with 20 hydrated lime added. The direct effect of buffering upon yield, if any, is obscured by the differences in the initial pH value.

Discussion

When mushrooms are cultivated in pots the conditions especially with regard to surface area of soil and amount of compost are not identical with those found in practice. It would therefore be unwise to extend the results obtained on the pots too far as representing conditions on the beds. However, the results from the pot experiment should give some indication of the general tendencies found in cultivation on a large scale.

Mushroom mycelium has been shown to have a definite aggregating effect on soils of poor structure and in a soil of good initial structure the continued breakdown of the soil structure by watering was arrested when mycelium became established. In the clay loam subsoil the mycelium has been shown to improve the water stability of the aggregates.

The effects of watering have been studied on one soil only, but these results are interesting. Increasing size of water application causes increased breakdown up to a certain point, and waterings in excess of the amount of water required to bring the soil moisture content up to this point cause little or no further increase in the destruction of soil aggregates. It is also interesting to note that the addition of the same amount of water to this soil per week brought about less breakdown if applied in two separate waterings at 3-4 day intervals than if applied all at once.

From the results from the pots cased with the soil of good original structure it appears that there is a danger that this structure may suffer considerable damage from watering during the period from casing to the time at which the mycelium has permeated the soil. The effect of this damage will be to reduce the permeability of the soil to gases at a time when the mycelium is actually growing into the compost and soil, and carbon dioxide production is likely to be rapid. The adverse effect of a casing soil of fine texture and lowered permeability has already been mentioned. Once the mycelium is in the soil and cropping has commenced this danger is not so likely to be important. The stability of the soil to

watering may be improved by the mycelium and the picking of mushrooms causes fresh soil to be placed on parts of the beds.

The binding effect of the mycelium, as well as increasing the stability of the soil aggregates and in some cases forming fresh aggregates, may operate so as to bind together the fine material resulting from the earlier breakdown of aggregates to form a ' mat ' which, when wet, is relatively impermeable. This matting effect has been observed frequently in soils removed from beds at the end of cropping.

In view of the effect of watering upon structure in the early stages of the cropping period, more information is required on the effect of different rates of watering ; the possibility of artificially increasing the stability of soils is also being investigated.

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MICROBIOLOGY DEPARTMENT

Miss C. Duncan

Experiments on Truffle, *Pseudobalsamia Microspora.* Diehl and Lambert.

Under certain undefined conditions compost treated with 0·01% and 0·1% copper sulphate has inhibited growth of Truffle. Moisture content appears to play quite a large part in this selective action. In order to study the possible influence of moisture a factorial experiment was planned using two batches of identically treated tubes with varying concentrations of copper sulphate, temperature, and moisture content ; in all seventy-two tubes were used. After ' casing ' with Truffle-infected compost one set of tubes was incubated at 29° C. and the other set at 25° C.

Horse manure compost was obtained with a moisture content of 51·5%. To give all tubes an equal start, moisture was added to bring the compost up to 65% after peak heating, calculated on the wet weight of compost. Two dozen tubes were treated with 0·01% copper sulphate, two dozen with 0·1% copper sulphate and the remaining two dozen with water alone to act as a control. The compost was weighed out, sprayed with copper sulphate solution or water and the treated compost was packed into boiling tubes as described in the Annual Report for 1950. After peak-heating, the tubes were spawned. Compost from one tube was dried to confirm that the moisture content was in the region of 65%. All tubes were incubated at 25° C.

Table 31. Copper sulphate, moisture, and temperature treatments of tubes infected with truffle

	None	0·01%	0·1%
Moisture and Incubation temperature	Wet 25° C. Wet 29° C. Normal 25° C. Normal 29° C.	Wet 25° C. Wet 29° C. Normal 25° C. Normal 25° C.	Wet 25° C. Wet 29° C. Normal 25° C. Normal 29° C.

Six tubes received each of the twelve treatments

Table 32. Results of copper sulphate treatment. No. of tubes invaded by Truffle

	0%	0·01%	0·1% copper sulphate
W 25	4 out of 4	0	0
W 29	0	0	2 out of 5
N 25	0	4 out of 6	2 out of 4
N 29	0	0	0

In a few tubes mushroom mycelium did not grow or extraneous infection developed, making them useless before they were cased with Truffle

After two weeks each group of tubes was divided into two equal batches. Water was added to half of the tubes to raise the moisture content to approximately 70% (wet tubes). The remaining eighteen tubes had a moisture content of approximately 65% (normal tubes). All tubes were 'cased' with Truffle-infected compost and incubated at 25° C. The duplicate batch of thirty-six tubes was divided and treated similarly, but after 'casing' they were incubated at 29° C.

Growth of mushroom mycelium was satisfactory in sixty-one tubes, thirty-one tubes incubated at 29° C. and thirty at 25° C. Twelve tubes were invaded by Truffle as shown in Table 32.

There was a general tendency for Truffle to develop in tubes with the most rapid growth of mushroom mycelium, and tubes with Truffle tended to have higher moisture contents at the end of the experiment than other tubes of the same original group. However, neither of these effects was clear-cut enough to be considered definite.

It seems unlikely that the development of Truffle in these tubes was due to heat arising from the growth of the mushroom mycelium, as has been suggested in the case of Truffle in commercial beds. There remains possibility of active stimulation of Truffle either by living mushroom mycelium or by its metabolic products.

Trial of copper sulphate treatment for control of Truffle.

Although the laboratory experiments on control of Truffle by copper sulphate had only been intermittently successful, we decided to take an opportunity which occurred in July to try it on a commercial farm where Truffle was prevalent.

Accordingly one ton of compost was sprayed with a solution containing ½ lb. of copper sulphate, as it was being shaken out for filling the beds.

The compost treated with copper sulphate had 67·5% of moisture before peak-heating and a sample taken after peak-heating had 63% of moisture.

The treated area of bed was marked and was spawned and cased as usual with the rest of the house, local soil being used for casing. This soil had previously given a considerable amount of Truffle. None of the beds in the house produced any mushrooms in over two months. This soil was removed and the beds were recased with imported soil. They immediately produced a vigorous flush of mushrooms, followed by others which totalled up to a reasonable crop.

The point of interest to us was that a few small patches of Truffle developed on the main area of untreated compost, but none appeared on the compost which had been treated with copper sulphate.

The importance of this test must not be exaggerated. It was only one trial, without replication. Many more such trials, or several more elaborate ones will be needed to establish the value of the treatment for control of Truffle in practice.

We are indebted to Mr. A. G. Lamberth of Danesbury Nurseries, Potters Heath, Knebworth, for providing facilities and recording the results of this trial.

Experiments on control of " bacterial pit "

As in previous experiments, plots of 10 sq. ft. were used, on shelf beds where bacterial pit was common. These were sprayed with a range of dyes and other substances, most of them known to have bactericidal or bacteriostatic activity in some conditions. In each experiment control beds were sprayed with water, and all sprays were applied at 1 pint on 10 sq. ft. of bed.

The results are given below with the average number of mushrooms picked and the percentage of them which were free from pitting. Although the incidence of pitting was reduced in some cases, results were rather variable and satisfactory control was not obtained. Some of the irregularity was caused by the fact that " bacterial pit " only developed toward the end of the crop, when production was decreasing and mushrooms were often irregularly scattered over the beds.

Table 33. Effect of sprays on " bacterial pit "

Experiment No.		1.		2.		3.	
Spray		Mushrooms		Mushrooms		Mushrooms	
		total	% clean	total	% clean	total	% clean
Water		107	1	33	0	65	0
Safranine	0·1%	164	40				
	0·01%	0	—				
Bordeaux mixture	1 : 1 : 50	19	47				
	5 : 2 : 50	94	69				
Methyl violet	0·1%	105	32				
	0·01%	39	33	103	18		
Titan yellow	0·1%	36	14				
	0·01%	53	17				
Aniline blue	0·1%	155	16				
	0·01%	76	25				
Bismarck brown	0·1%	97	3				
	0·01%	95	13				
Malachite green	0·1%	33	9				
	0·05%					57	12
	0·01%	110	56	159	21		
Acid fuchsin	0·1%					83	2
	0·01%					52	4
Cotton blue	0·1%					63	0
	0·01%					45	0
Gentian violet	0·1%					78	19
	0·01%					37	0
Rose bengal	0·1%					66	7
	0·01%					42	20
Light green	0·1%					70	0
	0·01%					72	3
Methyl violet	0·1%					64	2
	0·01%					60	0

Samples received in the course of advisory work

The following fungi were indentified in samples received from growers, particularly during the periods shown.

Parasitic on Mushrooms

Dactylium dendroides (frequent, May—July).
Mycogone perniciosa (frequent, May—July).
Verticillium Malthousei (frequent, August).

Competitors or Invaders

Chaetomium sp.
Myxomycete (not identified further).
Oedocephalum fimetarium.
Papulaspora byssina.
Penicillium sp.
Pseudobalsamia microspora (frequent, August).
Scopulariopsis fimicola (frequent, February—May).
Sepedonium chrysospermum.
Sporendonema sp.
Trichoderma viride.
Vert-de-gris.

Apart from the identification and control of disease, two important causes of trouble which have been encountered deserve mention, although they have been described elsewhere.

Modern insecticides are extremely powerful and some of them are toxic to the mushroom if too much is used. It is important with all of them to use only preparations specifically recommended for mushroom growing by the makers, and to follow their directions carefully. Too frequent use can also be injurious, and the use of several insecticides at the same time is a doubtful practice until any particular combination has been proved safe. The same caution is necessary in using fungicides intended to control disease without injuring the mushroom. This must depend on use of the correct dose.

Another source of trouble is the improper use of creosote, which is well known, and of phenolic disinfectants. Both of these can cause anything from Rose Comb to complete failure to crop. They can be used in favourable circumstances and are used daily by some growers without any trouble, but the following points must be borne in mind.

Phenolic disinfectants must be used very dilute, about 1% is all that is necessary, and this is safe. It is particularly dangerous to use stronger solutions on large areas of absorbent material such as the softwood lining of a mushroom cropping house, which may then give off phenolic vapours during cropping.

Creosote should be high temperature distilled and should comply with BSS 144. Treated timber must be well dried before use. Recent observations by Dr. W. V. Peet, who has written a full account in the M.G.A. Bulletin, show that even good quality creosote can cause damage if used on unseasoned wood, even in shelf houses with good air space and ventilation. It should probably be considered unsafe to use creosote on any unseasoned wood or any hard wood, until more precise knowledge is available. Trays are particularly liable to cause trouble because of the

large area of exposed surface of timber and the small air space between timber and casing soil.

In some cases the trouble has been cured by subsequent treatment of the offending timber. On one farm a phenolic disinfectant which was causing Rose Comb was fixed by lime-washing the timber, which allowed normal mushrooms to develop until the lime was neutralised by an accumulation of carbon dioxide, which caused fresh evolution of phenolic vapour. Good ventilation kept this under control.

A more permanent cure was effected by washing the timber with a 10% solution of iron (ferrous) sulphate which presumably caused atmospheric oxidation of the offending substances. This has given some relief when applied to timber treated with phenolic disinfectants and with creosote.

Test of fungicides for control of " Bubble " (*Mycogone perniciosa*)

For many years Bordeaux mixture has been proposed as a mild fungicide for control of Bubble and other parasitic diseases of mushrooms, but it does not appear to have been widely used. Recently Sinden, Hauser & Hauser (1950) have reported good results in U.S.A. with dusts and sprays containing zinc ethylene bis-dithiocarbamate (" Zineb") in various proprietary formulations. This fungicide is not produced in Britain and in view of import difficulties we sought a possible alternative.

Tetramethyl thiuram disulphide (TMTD) is used here for some of the purposes for which " Zineb " is used in U.S.A., and seemed worth trying.

An experiment was therefore arranged to compare Bordeaux mixture and these two fungicides on mushroom beds known to be infected with M. perniciosa.

The Research Station had no beds available for this purpose and Mr. Stanley Middlebrook very kindly placed at our disposal 40 trays in a house filled with these trays, which included two different casing soils. Cawood soil is naturally infected with *Mycogone perniciosa* and usually produces a large proportion of diseased mushrooms if used without treatment. The Selby soil is normally clean, but is usually steamed on that farm. 20 of the experimental trays were cased with unsteamed, naturally infected Cawood soil, and 20 were cased with steamed Selby soil and were then sprayed with a suspension of spores of *M. perniciosa*. The trays were numbered off in blocks of four, and the four treatments, water, Bordeaux mixture, " Zineb," and TMTD were randomised in each block. In all cases 400 ml. of spray were applied to a tray of 6 sq. ft. (1 gallon on 67 sq. ft.).

The sprays used contained 5 oz. TMTD per 100 gallons, 1 lb. zinc bis per 100 gallons, and 2 lb. copper sulphate and 2 lb. hydrated lime per 100 gallons. The differences in strength were due to differences in the commercial formulations used, the two new fungicides being made up with 2 lb. of the commercial product used in 100 gallons. The trays were sprayed on the day after casing.

The trial was carried out in May and June in a Handcraft house filled with the trays of a normal crop, about 1,200 sq. ft. The house had five roof ventilators and four at ground level, which were open throughout the test. The trays were watered in the same way as the others in the house, averaging twice a week.

When they came into crop the yield from each tray and the number of diseased mushrooms were recorded in each flush. The following tables give the average results, which are fully representative because the trays were remarkably consistent in response to each treatment. They have been analysed and the standard errors of the means are given.

Table 34. Yields of healthy mushrooms. lb./sq. ft. in 5 flushes

Treatment	Cawood soil unsteamed naturally infected	Selby soil steamed artificially infected
Water	1·11	1·11
Bordeaux Mixture	1·22	1·35
" Zineb "	1·48	1·81
TMTD	1·40	1·81 ± s.e.0·09

Table 35. Number of diseased mushrooms removed per sq. ft. in 5 flushes

Treatment	Cawood soil unsteamed naturally infected	Selby soil steamed artificially infected
Water	43	44
Bordeaux Mixture	39	39
" Zineb "	10	1
TMTD	15	3 ± s.e.0·7

Table 36. Number of diseased mushrooms per lb. marketable in 5 flushes

Treatment	Cawood soil unsteamed naturally infected	Selby soil steamed artificially infected
Water	39	40
Bordeaux Mixture	32	29
" Zineb "	7	1
TMTD	11	2

" Zineb " and TMTD are both clearly superior to Bordeaux Mixture for control of Bubble under the conditions of the experiment, which were normal for a mushroom house in early summer, and both allowed better yields to be obtained. Control was much better in the artificially infected soil than in the Cawood soil, possibly because in the latter the spores are distributed deeper in the soil and would not all be reached by the fungicides.

There was no significant difference in yield between " Zineb " and TMTD. The difference in their effects on incidence of disease was small and its significance is doubtful, particularly in view of the difference in rates of application.

A comparison of the proportion of diseased mushrooms to yield of healthy ones shows no increase with successive flushes on the Cawood soil or with Bordeaux Mixture and water on the Selby soil, but there was a slight increase in Bubble in the fourth and fifth flushes in the Selby soil treated with TMTD, and a small increase with " Zineb."

It is noteworthy that in spite of the presence of 20 trays quite heavily infected with *M. perniciosa*, there was no transfer of the disease to any of the other trays in the house. The experimental trays were not isolated in any way and formed part of a block in which they were bordered on each side by other trays.

We are extremely grateful to Mr. Middlebrook and his Staff for facilities for the trial and for all the work of detailed recording which they did.

SYNTHETIC COMPOST

M.R.A. Formula a Commercial Proposition

Fred. C. Atkins

Technical Director, Noble Mushrooms Ltd.

When the Mushroom Growers' Association accepted the responsibility (with help from the Ministry of Agriculture) for financing the Yaxley Research Station until the new Glasshouse Station was in a position to take over, Noble Mushrooms Ltd. agreed to test the Mushroom Research Association's formula for synthetic compost on a commercial scale and report on its findings.

The report can be summarised very briefly: We are now using it to the total exclusion of horse-manure composts. In other words, it is a commercial proposition.

In average figures, our last 12 crops took 50 days from filling to first picking. All did over 2 lb. to the square foot, producing the 1st lb. in 17 days and the 2nd pound 25 days later. **The average yield in 11 weeks' picking was 2·8 lb./sq. ft.)**

This compares favourably with our 2·5 lb. average from horse-manure compost over the past two years. There are variations in yield between one house and another, but they are no greater than we had with horse-manure, and our experience in the preparation of synthetic compost is very limited compared with our accumulated knowledge of orthodox composts. The details follow :

House No.	Days between filling and cropping	Time taken to give			Yield in 11 weeks (lb.)
		1st lb.	2nd lb.	3rd lb.	
14	54	14	34	68	3·2
13	50	21	42	66	3·2
9	51	17	34	—	2·9
6	54	14	33	66	3·0
2	55	18	47	—	2·5
30	53	12	36	—	2·8
25	48	14	41	74	3·1
20	47	11	31	78	3·0
17	43	32	73	—	2·2
15	45	21	60	—	2·2
14	50	14	41	—	2·7
11	50	16	35	—	2·8
Averages	50	17	42	—	2·8

No-one will imagine, I hope, that synthetic compost is easier to prepare than horse-manure compost, but one does start with more or less identical materials, and it seems not unreasonable to hope that with experience one's technique will become more standardised than has been possible hitherto with widely differing manures. But initially it is very true that the one is as easily ruined in the composting process as the other.

The fact that the basic material in M.R.A. compost is long, resilient, fresh wheat straw gives rise to several problems :

1. **The straw has to be persuaded to absorb a great deal of water at the outset.** When we used to use heavy manure we added straw to it, and we used to wet that straw by the Noble Drip Method. Bales of straw placed beneath a drip pipe were saturated in 48 hours—except in a stiff frost. As we do not wish our stacking schedule to be upset by the weather, we now place our bales under spray lines in a Handcraft Hut. re-circulating any water running through the bales.

2. **As no amount of trampling can result in a really compact heap at the first stacking, the sides and ends tend to dry our very rapidly.** This drying out is reduced by surrounding the stack with a protective wall constructed of straw bales. (This is, in fact, the third stage in the march towards air-conditioned composting sheds—a concrete floor and a roof being the first two).

3. **The initial stacking is a slow process, for the material is much bulkier than a comparable weight of horse-manure, the chemicals have to be added, and much trampling is required.** Something like 45 man-hours is spent on putting down a synthetic compost for 1,000 sq. ft. firmed to 7 inches. Such a stack calls for about 3½ tons of straw which when saturated, shaken up, stacked, treated with chemicals and trampled at each 12-inch layer, occupies an area 10 ft. wide and about 25 ft. long when 6 ft. high. This bulk shrinks very rapidly as composting proceeds of course.

4. **The finished product contains so much longish straw that the weight of compost which can be packed into a given area (say 18—20 lb. per sq. ft.) is only about two-thirds that of average horse-manure compost.** The loose texture of synthetic compost presents a possible advantage in that a greater area of bed is covered, but we rather felt that, apart from a tendency for the bed to dry out rather quickly, the yield of mushrooms might be relative to the **density** of compost as well as to the depth of the bed.

The solution to most of these problems seemed to be to chop the straw before stacking, and for some time we were looking around for a suitable machine to do the job.

Concurrent with our inquiries was the International Conference on Mushroom Science, at which my old friend Monsieur Chapuis, from the French Jura, advocated the chopping of straw for synthetic compost. Our theories and plans received his full support. Describing his own experiments, he told the Conference : " For convenience in turning, the best results are obtained with straw chopped into three

or four-inch lengths. Chopped straw makes the laying of beds easier and gives more compactness, reducing the area filled but greatly increasingly the yield per sq. ft."

So we bought a " Robust " Kale Cutter and it proved admirable for chopping straw into lengths of not more than six inches. (The steady increase in the number of combine harvesters, and their effect on the physical condition of the straw, may well mean that we shall in future be using this straw and that it may not need any chopping.)

Our procedure to-day is as follows (adjusted to fill 1,000 sq. ft. of bed area). About 90 bales of fresh wheat straw are laid down in the Handcraft Hut, and watered until they have trebled their weight. They are then chopped into 6″ lengths or less and, as the stack rises, each 12-inch layer is covered with M.R.A. Activator One. Immediately before adding this activator the stack each time is well and truly trampled to get it as compact as possible. The completed stack is surrounded by bales of straw.

One week later we turn the stack inside out and upside down, watering those parts which have dried out, and trampling every foot or two as it rises. The second and third turns take place at weekly intervals, the material being put through a DLP Composter each time, and the protective wall of baled straw is always replaced.

After the stack has been composting for about 28 days, Activator Two is thoroughly mixed in as the compost is put through the DLP machine for the last time (or through the Robust Cutter if it is still longish, though this is unlikely). The same or next day the beds are filled to a depth of 11 inches and pressed down to occupy 7 inches.

From then on the procedure is as for horse-manure compost, except that it may be more important after spawning M.R.A. composts to wait three weeks before casing. We have had several " secondary fermentations " after peak heating which indicate that the period of composting may be more critical.

We mix our own Activators in a Plantool Mixer. It might be as well to print the revised grouping ; the quantities are the same as before. *The figures are per ton of dry wheat straw.*

Activator One	Cwt.	lb.	oz.
Dried blood (12% N)	3	0	0
Superphosphate		14	0
Gypsum		35	0
Sulphate of potash		14	0
Carbonate of lime		50	0
Manganese sulphate			12
Iron sulphate			12
Copper sulphate			2½
Aluminium sulphate			2½
Zinc sulphate			1½
Ammonium molybdate			1½
Boric acid			1½
Chromium sulphate			½

Activator Two	lb.	oz
Superphosphate	14	0
Gypsum	70	0
Potassium bromide		¼
Potassium iodide		¼

If you choose to buy and mix these ingredients yourself you may be asked some awkward questions regarding the minor elements : Do you want the " technical " salt, or " pure," " commercial," " basic," or " normal," for examples. All in fact are " normal " salts except the " basic " chromium sulphate ; and try to get " technical quality " in each case.

But accurate weighing, grinding (to pass a 1 mm. sieve if possible) and mixing is a dull and protracted operation, and most growers will prefer to buy their Activators ready-mixed from one of the following suppliers : **The Bradford Fertilizer Co. Ltd.**, of Whitefield Place, Girlington, Bradford, Yorkshire ; **Thomas Elliott Ltd.**, of Eagle Mills, 120 New Church Road, London, S.E.5 ; and **J. E. R. Simons, Ltd.**, of Harlow, Essex. You should order 4 cwt. of M.R.A. Activator One and 84 lb. of M.R.A. Activator Two, multiplied by the number of tons of straw (dry weight) you are putting down.

The following calculations are based on figures ruling during the last quarter of 1951 :

M.R.A. Synthetic Compost : Straw £18 ; blood £36 ; superphosphate 15/6 ; sulphate of potash 12/6 ; carbonate of lime 11/6 ; gypsum £1 ; trace elements £1 0s. 6d. Total = £58 per 1,000 sq. ft. of bed.

Horse-manure Compost : 13 tons heavy manure £52 ; 1 ton straw £5 ; 3 cwt. gypsum £1. Total = £58 per 1,000 sq. ft. of bed.

Horse-manure used to take us about 16 man-hours fewer than does synthetic compost, for 1,000 sq. ft. of bed. This extra £2 on the bill is many times offset by the advantage of being able to put a stack down at any moment regardless of manure contractors difficulties and British Railways delays.

Were Urea to be commercially available, the £36 for blood could be reduced to about £7. This in turn would bring down the cost of synthetic compost below £30 per 1,000 sq. ft. (i.e. to half the price of heavy horse-manure).

Conclusions

A properly-prepared M.R.A. synthetic compost is almost indistinguishable from fully-composted horse-manure. It is at least equally productive. It provides an opportunity for standardising the composting procedure. Its materials can be stored for use at a moment's notice. The cost to-day is about £85 per 1,000 sq. ft., which is what the best horse-manure compost would cost us. Further research can cheapen and improve it.

Such is our report, based on the many experiments conducted for Noble Mushrooms Ltd. by Managing Director B. A. Noble, assisted by my brother Peter Atkins and Foreman David Gee, to all of whom I am indebted for the foregoing facts.

STRAW SUPPLIES AND SOME POSSIBLE ALTERNATIVES

R. L. Edwards

Straw—preferably wheat straw—is the real basic material of mushroom growing, whether it forms the bedding in stable manure or is used to make synthetic compost. During the last 18 months the price of wheat straw has more than doubled and at times it has been very scarce even at present prices.

One of the jobs we try to do at the Research Station is to keep an eye on materials used by the mushroom grower, and when straw supplies looked a bit doubtful we made some enquiries about the position and prospects.

Most of the information on available supplies came from the Development Commission Survey of Agricultural Forestry and Fishery Products and their Utilization, an organisation set up to collect statistics and find uses for the many waste materials coming within their scope.

It has been estimated that the present annual output of mushrooms is 30,000,000 lb. Taking an average yield as 125 lb. of mushrooms per ton of manure, containing 25% of its weight of dry straw, this output would require 60,000 tons of wheat straw. This may be compared with the following figures for straw production :—

Development Commission Survey's Estimates
Production of Cereal Straws in U.K. in 1948 (tons)

	Varieties			Total
	Wheat	Barley	Oat	Cereals
Output in 1948	2,400,000	1,700,000	3,500,000	7,600,000
Used on farms	2,083,000	1,520,000	3,381,000	6,984,000
Sold off farms (for feeding, bedding town horses, industrial use, etc.)	317,000	180,000	119,000	616,000
including—				
paper making	60,000	8,500	24,500	93,000
other industrial uses, mainly packing	190,000	131,000	—	321,000
unaccounted for	67,000	40,500	94,500	202,000
The Survey estimates that the following could be spared from agricultural use :—				
	500,000	300,000	200,000	1,00,0000

It will be seen that the amount of straw needed for mushroom growing is small in comparison with the total output, but is quite a large part of the amount at present sold off the farm. Assuming that farm consumption remains steady, any substantial change in industrial use of straw could have a considerable effect on the supply available for mushroom growing. It seems probable that individual growers could without difficulty arrange to buy a year's supply of straw immediately after harvest, and they would not be in any serious danger of shortage.

In a trial with synthetic compost at the Mushroom Research Station, a mixture of wheat and barley straws in equal parts gave the same yield as wheat straw alone. Barley straw gave 10% less, which is not a great difference, but it was obvious from the appearance of the compost that it would be much more easily spoiled. The barley straw is relatively soft and would make a soggy compost if not handled with care.

There are quite a lot of other waste fibrous materials which **might** be usable for mushroom compost. The D.C. Survey gives the following quantities which were destroyed in 1949 :—

linseed straw	50,000	tons	(dry weight)
mustard straw	6,500	,,	,, ,,
pea straw	131,000	,,	,, ,,
hop bines	50,000	,,	,, ,,
oat husks	70,000	,,	,, ,,
flax shives	36,000	,,	,, ,,
wood waste, at least	60,000	,,	,, ,,
(sawdust, chips, shavings, etc.)			

Presumably similar amounts would be available in other years, though the output of linseed straw is said to be falling.

Another suggested material is bracken, which is known to compost well, and I believe has been used by a few growers. I have no reliable estimate of the quantity available, and of course it only grows in certain areas. Bean straw has also been used successfully.

The recent increase in the price of straw (£3 per ton is equivalent to about 2d. per lb. of mushrooms, depending on yield) makes cheaper fibres attractive to the speculative grower, but any trials should be made on a modest scale, with the mental reservation that they may be complete failures. Several trials should be made in this way with a sharp eye on possible difficulties, before using any new material on a full commercial scale. These fibrous residues could be tried as substitutes for part of the straw in horse manure, with or without activators, or in synthetic composts. For either purpose the proportions of added N, P, K may have to be altered, but the physical texture may be even more important. This was seen in the case of barley straw already mentioned. The compost must be porous to air during composting, and at the same time must be compact to hold enough food material for the mushroom in the bed.

It is quite possible that with patient trials over a year or two quite good compost might be made from some of these materials. On the other hand they might give persistent failures, and absorb much time.

It is for each grower to decide whether this saving in cost compared with straw is worth the trouble of perfecting his technique with another fibrous material. Certainly it can only be worth while if the alternative is cheap and plentiful, and gives consistent results.

The maximum possible saving is the price of the straw, which at £8 per ton, if a ton of straw fills 400 sq. ft. of bed, is £20 per 1,000 sq. ft. This should be considered in relation to the probable income, from say 1,600 lb. of mushrooms at 3s. 6d. per lb., of £280. At this price it is not worth sacrificing even 2 oz. per sq. ft. to save the total cost of the straw, if cost is the main consideration. Where wheat straw is literally unobtainable there is a definite case for trials with some of these other fibres.

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